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A NEW HIGH LOAD CAPACITY HYBRID LOCOMOTION ROBOT CAPABLE TO CLIMB STAIRCASES.

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ABSTRACT
Architectural barriers still exists for the wheelchair users in many cities and buildings, and it is very difficult to eliminate all of them. There have been a number of wheelchairs designs that claim to overpass these barriers. The authors of this paper believe that most of these designs have serious problems related to: its low payload capacity, the lack of safety or its impossibility to overpass a wide variety of obstacles.
This paper describes the mechanical devices of a novel wheelchair capable of climbing most common obstacles a wheelchair could face in modern cities. The key feature of the mechanical design is the use of two decoupled mechanisms: one to climb a single step, and other one to positioning these climbing mechanisms into the staircase, ensuring stability. This decoupling makes possible many different climbing strategies becoming the overall mechanism extraordinary versatile. This paper will show some strategies that could make the overall control of the systems easier. Some experimental results of the climbing process for different obstacles are also presented in order to emphasize the proper environment adaptation of this novel wheelchair.

1. INTRODUCTION
Powered wheelchairs have been in use for many years now, and it is unquestionable that they greatly improve the mobility of handicapped. Nevertheless, a wheelchair becomes a useless device when faced with an architectural barrier and, as a result, there have been a number of wheelchair designs that claim to be able climb staircases.
The first commercial models utilized platforms with a caterpillar based locomotion system, which transported the standard wheelchair with the passenger over staircases. Other designs are based on several wheels arranged in a rotating cluster. There are mechanisms that use a single rotating link. While the mechanical design is quite simple, the chair is very sophisticated since it relies on dynamic control to maintain the upright position (IBOT 3000). There are alternative designs which use several rotating clusters, but this solution implies a higher weight.

2. MECHANICAL SYSTEM DESCRIPTION
The proposed mechanism solves the staircase climbing problem splitting it into two sub problems: the first problem is single step-climbing and the second one is front and rear axle positioning. Every sub problem is solved by a specific mechanical. The figure 1 shows the scheme of the two devices.

2.1. Climbing mechanism
The *climbing mechanism* solves the first sub problem, and it is labelled with 1 in figure 1. This mechanism is able to save a single step; therefore the wheelchair has got two climbing mechanisms. The mechanical design process makes an effort in order to get adaptability of the system to different obstacles geometries.

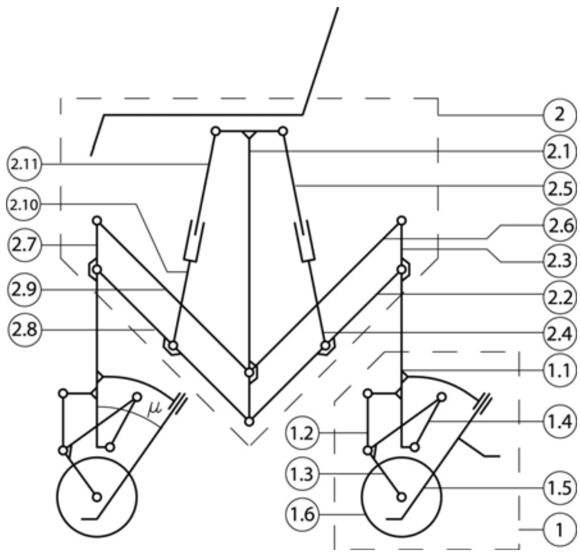

Figure 1. Cinematic scheme of the prototype

The system has been also designed in order to be easily controlled. This requirements force the system to be always in a stable equilibrium. This objective is satisfied ensuring at every moment a wide support polygon with four contact points. Another important feature of the systems is its high payload capacity. Table 1 shows the payload capacity and weight-payload ratio for other climbing systems. The ratio of the presented one cannot be achieved with tracks or rotating wheel clusters.

Table 1. Weight and weight-payload capacity ratio for climbing prototypes.

Vehicule	Locomotion system	Weight (kg)	Weight-Payload capacity ratio
Presented vehicle	Hybrid locomotion	72	2.53
XEVIUS [3]	Single Tracks	65	0.92
IBOT 3000	Wheel cluster	131	0.86
M. J. Lawn's Stairclimber	Wheel cluster	160	0.5
HYBTOR [4]	Hybrid locomotion	160	0.37
ALDURO [5]	Hybrid locomotion	1500	0.32
Nagasaki Stairclimber	Double Tracks	250	0.32

The positioning mechanism climb the step deploying a sliding support joined to the axle with a prismatic joint (1.5 in figure 1) in a fixed angle μ. A four link mechanism is also added. This mechanism allows the wheel to move backwards to avoid the interference from the step (1.1, 1.2, 1.3 and 1.4). This new degree of freedom must be cancelled with a electromagnetic lock. The maximum step height that the wheelchair can surpass is 220 mm.

2.2. Positioning mechanism

The second device is a closed-loops mechanism called positioning mechanism (labelled 2 in figure 1). The positioning mechanism is the system that ensures the verticality of the wheelchair and to position the front and rear climbing mechanism to accommodate the overall slope. The system requirements are the following: high payload capacity (due to the high payload capacity of the prototype), compact design and light weight. In attempt to fulfil these requirements the authors think that the best choice is a Closed-loop mechanism. Closed-loop mechanism presents very good performances in terms of rigidity and ability to manipulate large loads.

A closed-loop mechanism is proposed, where the mobile platform is connected to the base by two cinematic chains (2.6 and 2.9 in figure 1). The main advantage of this scheme is the high stiffness, due to multiple closed loops. The chair seat is joined to the part 2.1. Furthermore, the 2.3 and 2.7 parts are the mobile platforms where the climbing mechanisms are attached. The movements of the mobile platforms are driven by two linear actuators (2.11 and 2.5). Figure 2 shows simulations using MEF for a 1960 N load proving the mechanical rigidity. This mechanism have got two degrees of freedom that make possible generations complex trajectories for the chair platform.

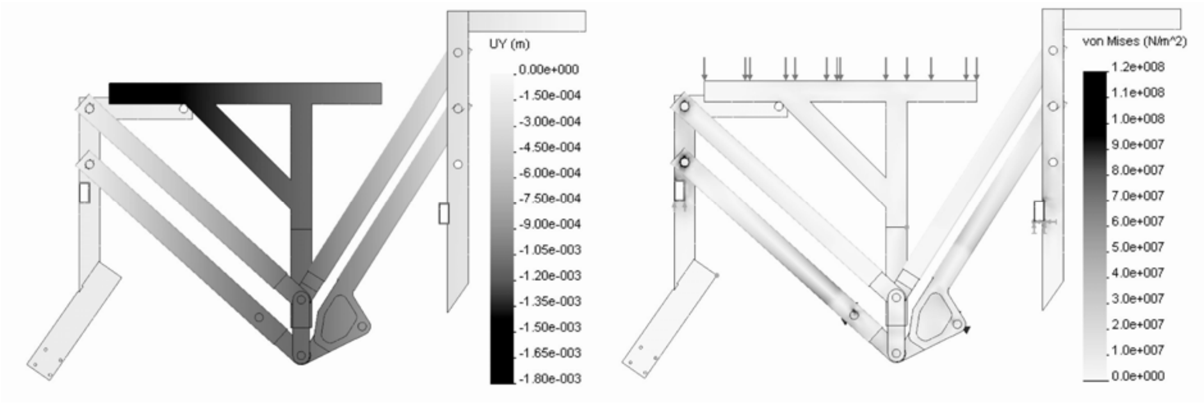

Figure 2. Displacement (left) and Von Misses stress distribution (right) for a 1960 N load.

3. EXPERIMENTAL RESULTS.

A three steps staircase has been built for the experimental analysis. The experimental results are been collected with a Optotrack system. The displacement data acquisition was developed with three IR cameras and several reflecting spots located where the instant position must be known. Figure 3 shows the experimental set up.

Figure 3. Experimental set up.

Figure 4 shows the experimental results. These results are the trajectories of the two points of the chair platform (1 and 2). The reflecting spot number 3 shows the trajectory of the rear wheel and number 5 the trajectory of the front wheel. The reflecting spot number 4 shows the trajectory of the front axle while the wheelchair climbs a three steps staircase.

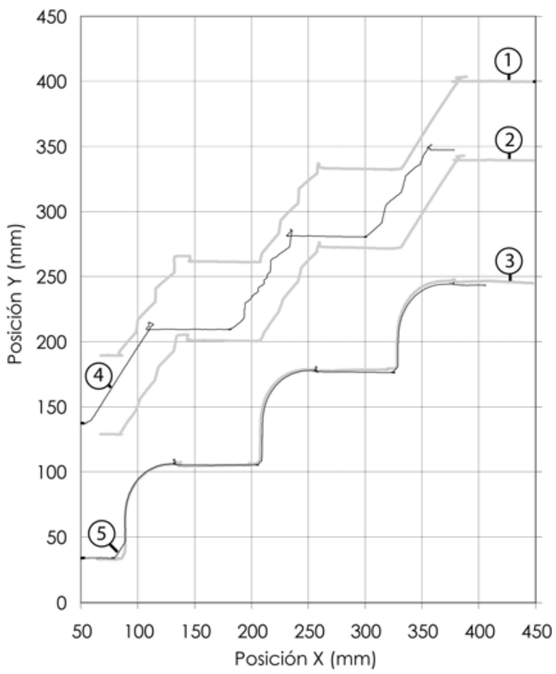

Figure 4. Trajectories of the reflecting markers..

5. CONCLUSIONS

A new mechanical device able to ascend and descend staircases has been presented in this paper. Its main features are: a) this is very stable as its weight is always transferred to horizontal surfaces, b) the mechanism keeps the verticality of the chair with a minimum control effort, c) it has additional degrees of freedom that allow motions and control strategies that take into account the comfort of the passenger (i.e. maximum acceleration and inclination of the wheelchair). The consequences of the previous features are that: a) the wheelchair exhibits larger ratios between the maximum transportable payload and the chair weight, or between that maximum payload and the power needed for the actuators than other wheelchair mechanisms for climbing staircases; b) the trajectories of the centre of mass of the wheelchair can be made more comfortable for the passenger with less control effort than in other existing mechanisms.

6. REFERENCES

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