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Bipedal walking robot platform with a vertically stabilized base usable as a bipedchair for disabled people

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Keywords: walking robot, biped locomotion, actuator, centre of gravity.
Abstract: The article deals with the design of a concept for a mobile robotic platform for transporting equipment or people. For disabled people, this system can represent an alternative to a wheelchair with better mobility in an urbanized environment. The proposed solution is unique in that it maintains a stabilized vertical position of the base.

1 Introduction

A large number of people have a medical handicap and cannot walk with their own feet. These are different diagnoses that do not have a favourable prognosis for improving the ability to walk in normal conditions. There are also cases where it is a permanent loss of mobility with the help of the lower limbs. For these cases, it would be appropriate to design a suitable device that would replace walking with the legs. Standard wheelchairs are a solution that often has a problem with obstacles that occur in urbanized environments, so there is room for walking structures. However, commonly used kinematic walking structures create a side-to-side rocking motion to maintain static and dynamic stability while walking. The application of this conventional way of walking would mean uncomfortable walking for a person. It would therefore be a biped chair that could handle obstacles such as stairs and curbs and other unevenness in the exterior.

The goal is to design a kinematic structure with as few degrees of freedom as possible and at the same time a good ability of mobility with minimal swaying movements to the sides. A small number of degrees of freedom also means a small number of actuators, and thus the energy requirements and range of the created structure also decrease. Walking structures have a disadvantage in terms of energy balance compared to wheeled structures, so suitable kinematic structures with a lower number of degrees of freedom could be a better solution. [1-29].

2 Robotic platform concept design

The first concept (Figure 1) contains three degrees of freedom in each leg and uses three rotary actuators in both legs. This simplified model represents the simplest structure that is similar to human kinematics.

One actuator would have to be located in the hip joint. The second actuator would have to be located in the knee joint and the third actuator could be in the ankle joint. The movement could be realized by crossing each other's feet (Figure 2).

However, the use of this kinematics entails a rocking motion with a large change in the position of the base of the robot in the vertical direction. If we consider that a person who is being transported would be placed in this base, then this movement is very uncomfortable.

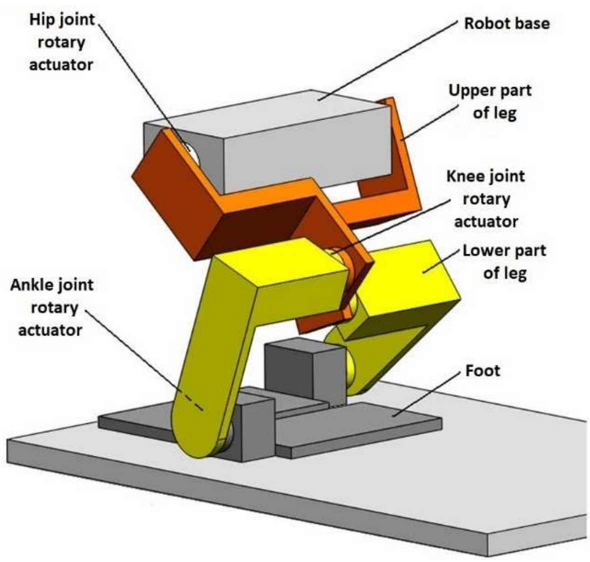

Figure 1 Biped robotic platform concept A

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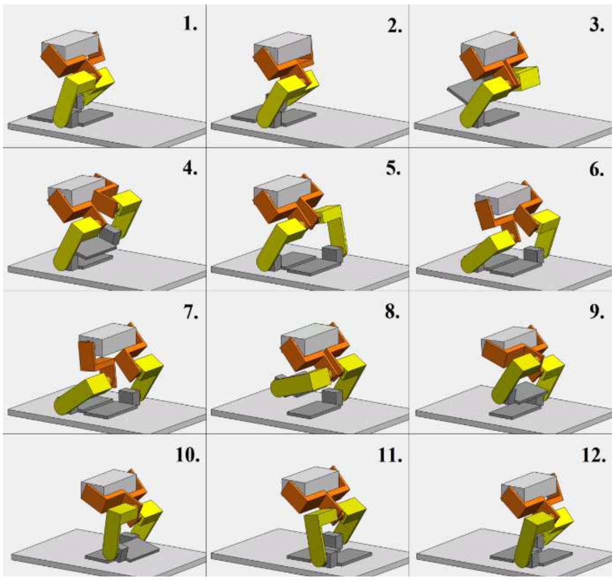

Figure 2 Walking algorithm of biped robotic platform concept A

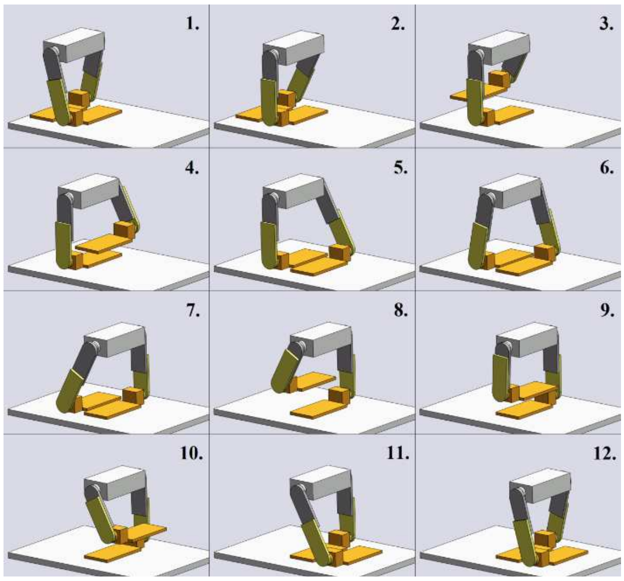

Figure 4 Walking algorithm of biped robotic platform concept B

Another robotic platform concept (Figure 3) no longer takes inspiration from human kinematics, but also includes a linear actuator and two rotary actuators in each leg. The linear actuator replaced the rotary actuator in the knee and thus created the possibility of lifting the leg while crossing the other leg without vertical displacement of the robot base (Figure 4). In terms of energy, however, this concept is still demanding, and the effort is to reduce the number of actuators even more.

Another concept is a design with two actuators in each leg (Figure 5), while the rotation is performed in the ankle joint and the linear movement of the actuator is performed in the hip joint, where this linear actuator is used to realize just the crossing of the legs and the compensation of the vertical movement activity so that the robotic base did not change its vertical position (Figure 6). This concept provides with two actuators the possibility of walking, even while maintaining the vertical position of the base.

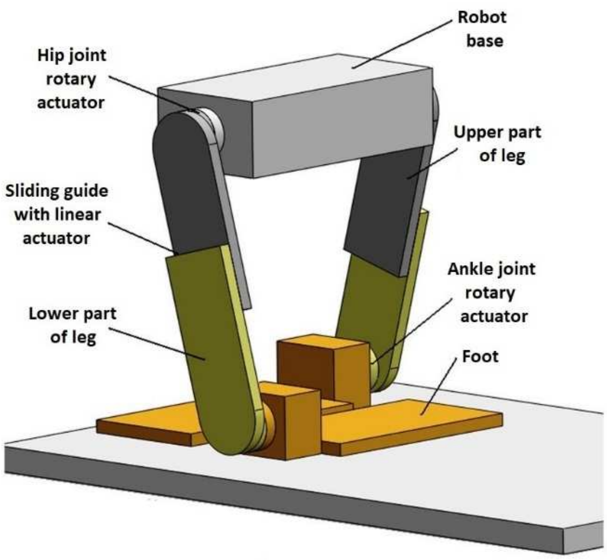

Figure 3 Biped robotic platform concept B

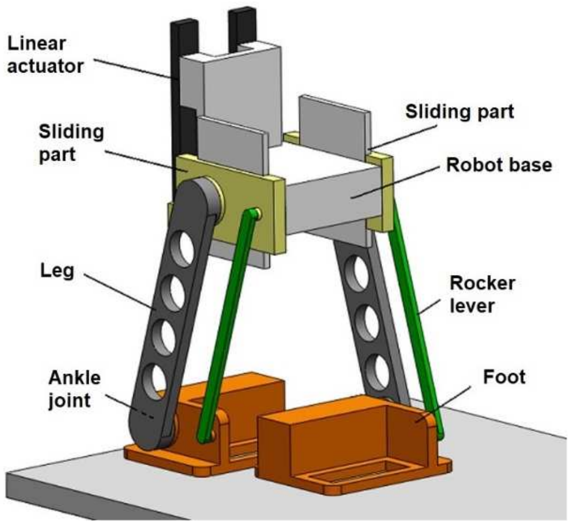

Figure 5 Biped robotic platform concept C

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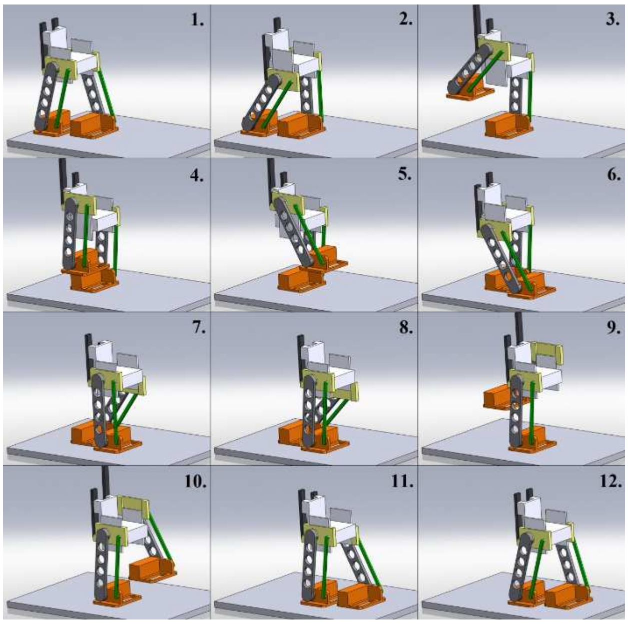

Figure 6 Walking algorithm of biped robotic platform concept C

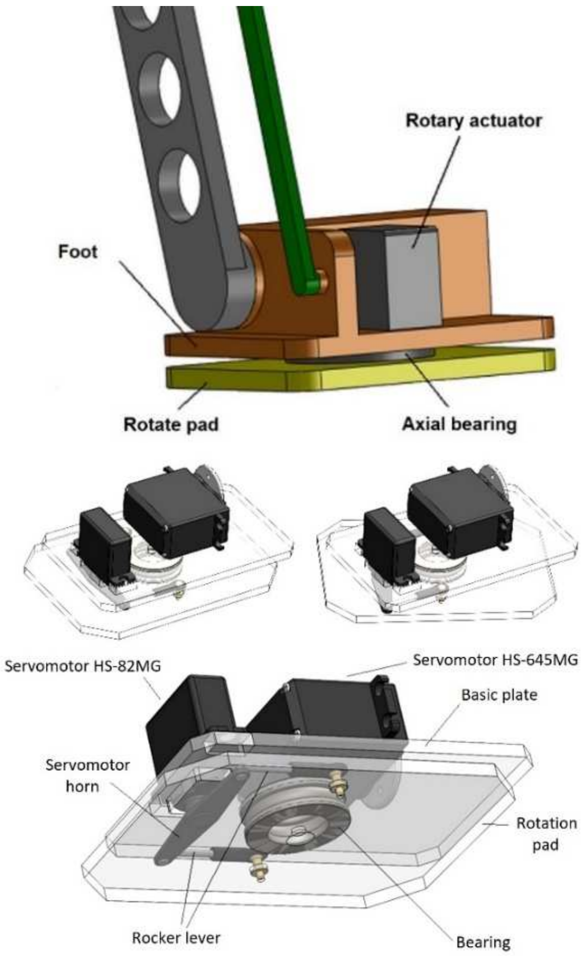

Figure 7 Rotating foot for changing walking direction

The concept (Figure 5) in this form is only applicable for walking in one direction. In order to be able to change the direction of walking, a rotating mat with another rotary actuator is proposed for the feet. This actuator will be located in the foot of the robotic platform. Such a rotating foot will allow the entire robot to be turned on the spot in the range of ±90° (depending on the type of servo drive), which is not possible with conventional kinematic concepts and requires a much larger number of actuators for turning.

The final concept (Figure 8, 9) of the walking robotic platform would thus contain six actuators, and four of them rotary actuators would be located in the robot's feet. If the accumulators are also placed in the lower parts of the platform, then it will mean that the overall center of gravity of the robotic platform will be low and thus the robotic platform will have better stability when walking.

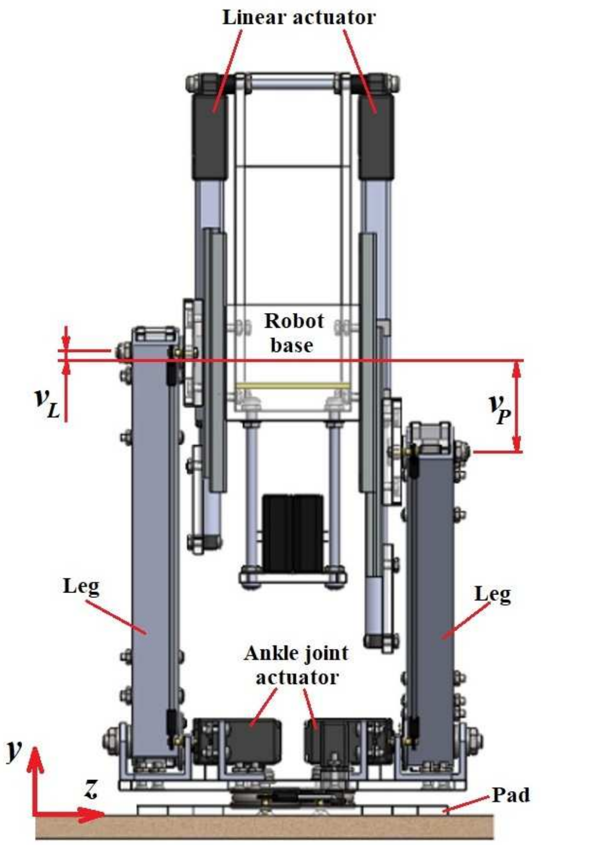

Figure 8 Final design of the walking robotic platform - front view

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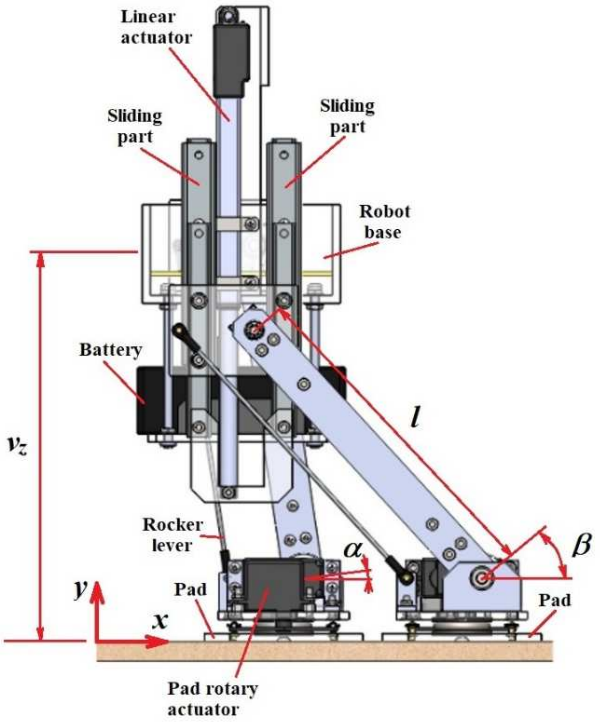

Figure 9 Final design of the walking robotic platform - side view

3 Simulations of the movement of the robotic platform

A mathematical model of the robotic platform was created from the proposed kinematics. The walking simulation confirmed the ability to walk for the proposed concept while also maintaining a stabilized vertical position (Figure 10, Figure 11). The ability to change the direction of walking is also important for the application of the structure for movement in space. The rotation of the robotic platform was simulated (Figure 12) and the results also confirm the usability of the proposed structure.

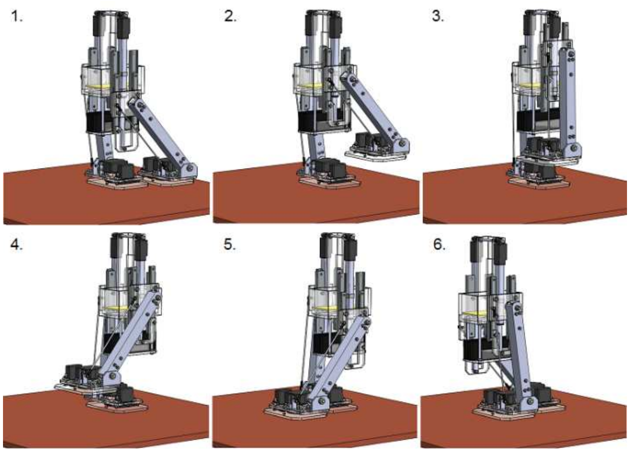

Figure 10 Walking simulation of the designed platform - CAD model

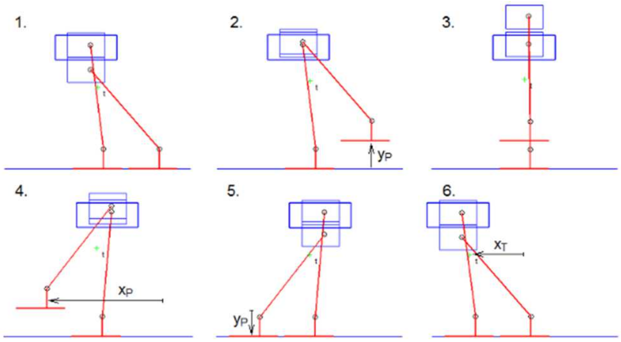

Figure 11 Simulation of walking of the proposed platform - math model

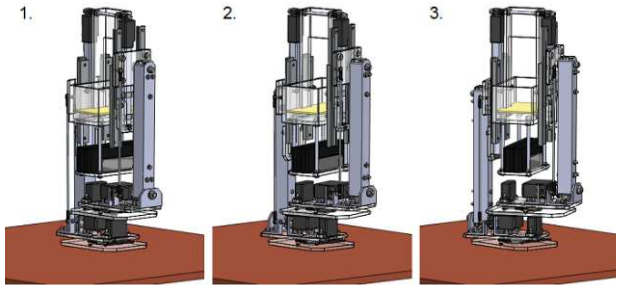

Figure 12 Simulation of the rotation of the designed platform

4 Conclusion

In the thesis, a robotic platform of a two-legged walking structure was designed, which can also be used for "bipedchair" applications as an alternative mobility solution for disabled people who have problems with walking. During the design, emphasis was placed on the minimum number of degrees of freedom and thus also the minimum number of actuators, which means minimum energy consumption. Energy consumption is also influenced by the kinematic arrangement of the platform itself. The proposed solution has unique properties, as it allows maintaining a stable vertical position of the base of the robotic platform, where a transported passenger could be placed at the same time. Simulations of the movement of the structure proved the correctness of the proposed solution.

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