

# Design of Two Legged Robot

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Received October 15, 2013; Revised October 30, 2013; Accepted November 19, 2013

**Abstract** Paper deals with two legged robot. The aim was to design the two legged robot with minimum actuators and low power consumption with respecting of robot stability. Another important aim was to find solution with stabilized base plate because of the using of navigation and obstacle sensors and CCD camera for teleoperator remote vision.

**Keywords:** robot, legged locomotion, actuator, stability

**Cite This Article:** Daniel Šimšaj, Michal Kelemen, Ivan Virgala, Tatiana Kelemenová, Erik Prada and Tomáš Lipták, "Design of Two Legged Robot." *American Journal of Mechanical Engineering* 1, no. 7 (2013): 355-360. doi: 10.12691/ajme-1-7-40.

## 1. Introduction

Mechatronics grows up last years as research and business approach to product design and developing. It is possible to say that almost every sophisticated product has mechatronic background. The product involves new functions as monitoring of its state parameters - self-diagnostic, self-repairing, guider to easy use with interactive user-friendly interface, self-calibration, remote wireless communication with user, events history saving, protection before damaging etc. Products with these properties are very attractive and preferred by customers. These products also ensure the business successful and profitable position on unstable market. All these mentioned facts are as the motivation for teaching of the mechatronics approach to product design and development [1-9].



Figure 1. Two legged robot Wirgil

Also legged robots have been developed as didactic model for training on mechatronic courses. Students can propose the algorithms of locomotion and they can also make optimization of locomotion with experimental verification. Practice of feedback position controlling

under variable loading is allowed on these models. More complex tasks are as locomotion through the rough terrain with obstacle avoiding with respecting of their stability.

Two legged robot "Wirgil" has been developed in year 2009 [10,11]. The robot Wirgil has good manoeuvres abilities and it uses six rotational position servos (three for every leg). A big disadvantage of the robot is that machine body (with obstacle sensor, CCD camera etc.) makes swinging motion during the locomotion. Obstacle sensing was complicated and view from CCD camera was unstable. Also, if any manipulator is mounted on base plate, than end effector handling could be very hard or impossible.

The paper deals with design of two legged robot for didactic purposes with stabilized base for sensors.

## 2. Design of Kinematics Arrangements

Designed variants have common significant novelty, that base plate (place for sensors, CCD camera or manipulator) is stabilized. Robot doesn't have to do swinging motion during the locomotion. It means that obstacle sensing, manipulator end-effector handling and video capturing is easier, than before.

Hip joints are mounted under the base plate and the have common axis of rotation. All variants are based on principle of step over locomotion. Consequently, it causes that it is not necessary to make swinging motion for moving of centre of gravity (for maintaining of robot stability).

Base plate is also maintained in equal high over the ground. Also, it is possible to change desired value of high of base plate. Designed variants differ mainly in count of actuators and kinematic arrangement.

On the base of designed kinematic arrangements, the CAD models have been created in SolidWorks

environment. These models have been used for walking simulation – motion study. These motion studies show results (base plate position, time dependence of loading of actuators, time dependence of consumed energy).

**2.1. Kinematic Arrangement – Variant A**

This arrangement **Figure 2** has 6 DOF (degrees of freedom). Both legs have 3 planar joints (hip, knee and ankle joint). Every joint is actuated with position servomechanism.

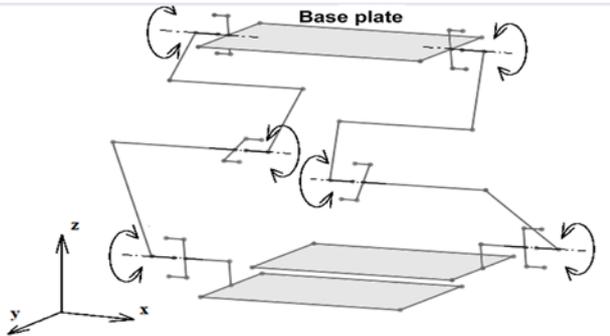


Figure 2. Kinematic arrangement – variant A

**Figure 3** shows the CAD model of kinematic arrangement used for walking simulation.

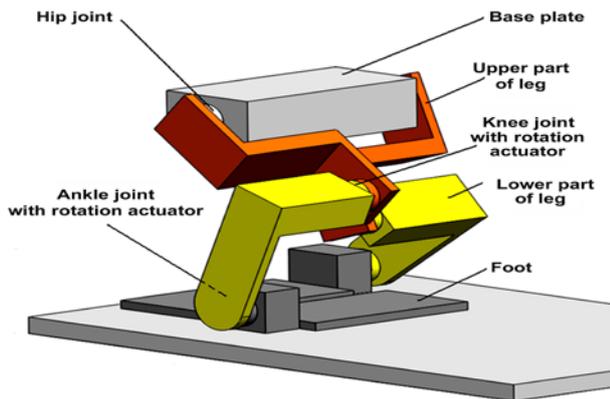


Figure 3. CAD model of kinematic arrangement – variant A

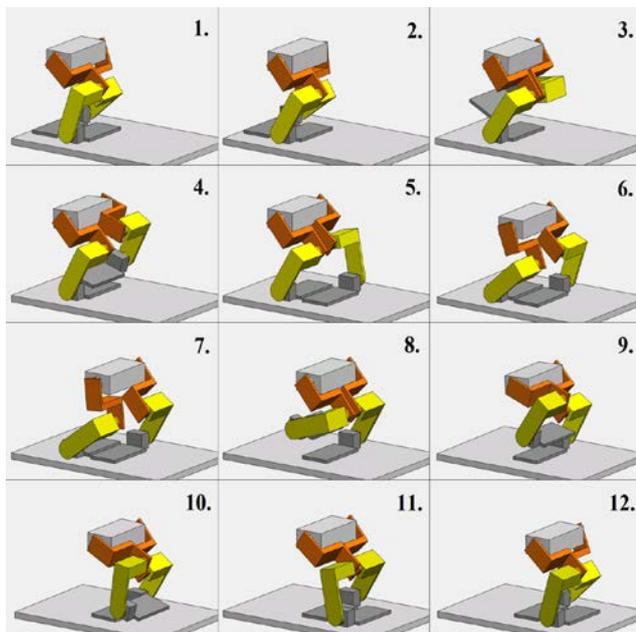


Figure 4. Walking simulation with CAD model of kinematic arrangement – variant A

Walking phases **Figure 4** obtained from simulation are shown on **Figure 4**. Walking starts in position 1 with removing of base plate in forward direction – position 2. It means that centre of gravity is shifted to right foot. This motion is realized with simultaneous motion of every rotation servomechanisms. After that, left leg is lifted – position 3 and left foot is moved before right foot – position 4 and 5. Centre of gravity is shifted to left foot (base plate is shifted forward) – position 6 and 7. These steps are also realized with right leg - position 8 – 12. Both feet should be parallel with ground before placing foot to the ground, because of ensuring the better stability of the robot.

**2.2. Kinematic Arrangement – Variant B**

This variant **Figure 5**, **Figure 6** has also 6 DOF, but it has only 4 planar joints (hip and ankle joints). Other 2 DOF are designed as linear link (instead of knee planar joints). Planar joints are actuated with rotational position servomechanisms and linear actuators are used for both linear links.

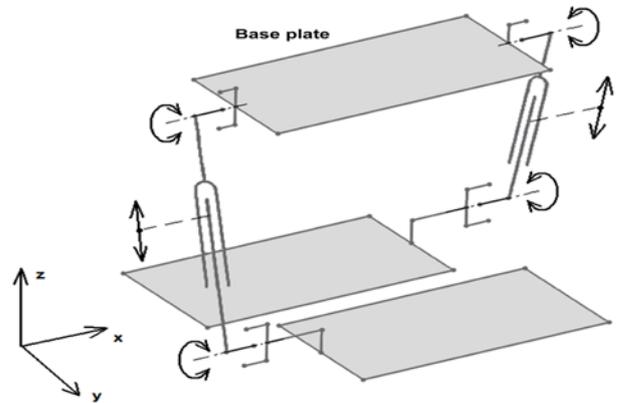


Figure 5. Kinematic arrangement – variant B

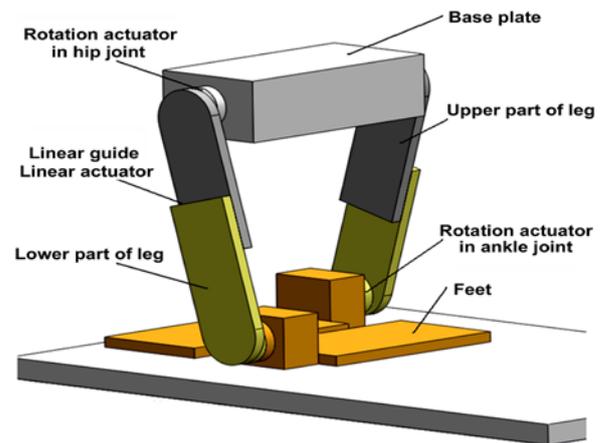


Figure 6. CAD model of kinematic arrangement – variant B

Walking of the variant B **Figure 7** starts with moving from starting position 1 to position 2. Centre of gravity is moved to zone of right foot. All actuators have to move simultaneous. Left leg plugs in with linear actuator (position 3), so left foot is lifted up. Next step is reposition of left foot in forward direction before right foot (position 4 and 5). Left foot should be parallel with ground in position 5, because of ensuring the robot stability. In other case the loss of robot stability occurs. Simultaneous motions of all actuators cause the removing of the base plate in forward direction (position 6). Analogically, the

next steps (position 7 to 12) make reposition of right foot in forward direction.

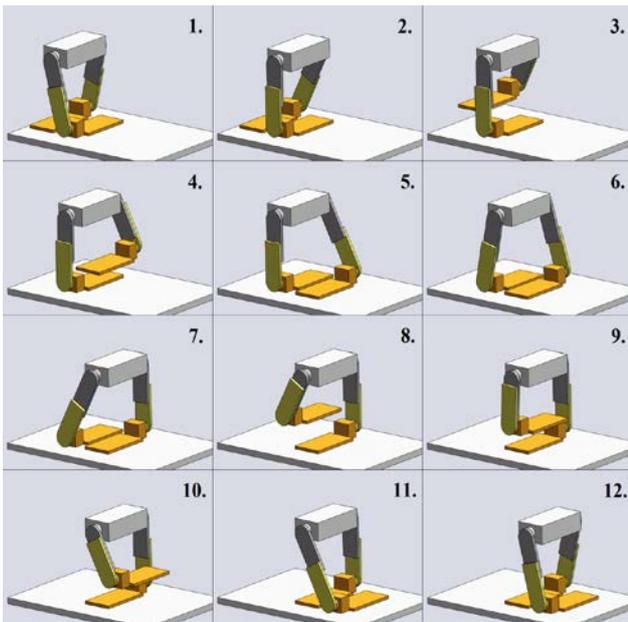


Figure 7. Walking simulation with CAD model of kinematic arrangement – variant B

### 2.3. Kinematic Arrangement – Variant C

Variant C Figure 8, Figure 9 has 4 DOF. Two DOF are realized with linear links and parallelogram mechanism. Parallelogram mechanism ensures the parallelism of feet and ground.

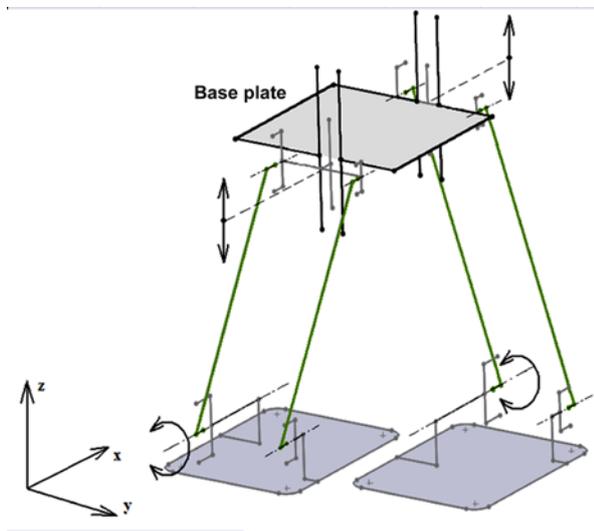


Figure 8. Kinematic arrangement – variant C

The parallelogram mechanism consists of four planar joints and two parallel levers with equal length. Rotational position servomechanism is designed as actuator for the parallelogram and this servomechanism is placed in the foot. The placement of servos in the feet are suitable, because of better stability of robot (centre of gravity is lower). Another two DOF are formed from linear links actuated with linear actuators. These linear links enable the lifting of overall parallelograms with foot.

Walking sequence of the variant C Figure 10 starts with starting position 1. Simultaneous motions of all actuators enable removing the centre of gravity to floor projection

of left foot (position 2). After this, it is possible to lift right foot without of loss of robot stability. So, right foot with overall parallelogram is lifted up (position 3). Rotation of actuator placed in right feet (ankle joint) causes the reposition of right feet in forward direction before left feet (position 4 and 5). Linear actuator drops the right feet to ground. Positions 7 and 8 represent the reposition of centre of gravity to floor projection of right feet. Analogical, the left foot is moved in forward direction (position 9, 10 and 11). Walking step position 12 is the same as position 1. Steps are repeated again.

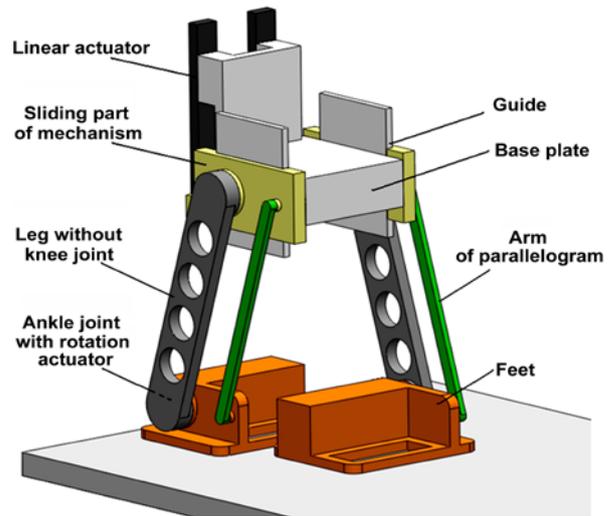


Figure 9. CAD model of kinematic arrangement – variant C

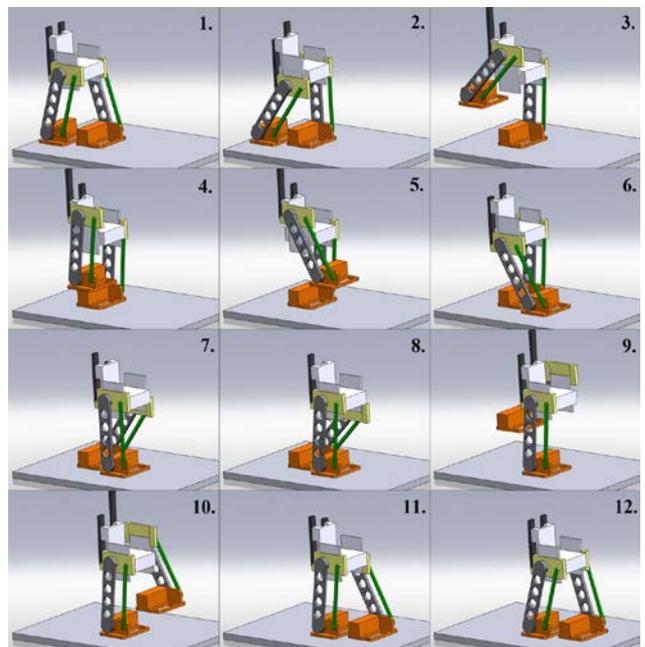


Figure 10. Walking simulation with CAD model of kinematic arrangement – variant C

### 3. Power Consumption of Designed Variants

Simulations of designed variants allow obtaining power consumption. This viewpoint helps to evaluate designed variants. This criterion is also important, because robot will operate with energy stored in accumulator placed in robot body. Figure 11 shows power consumption in time for designed variants.

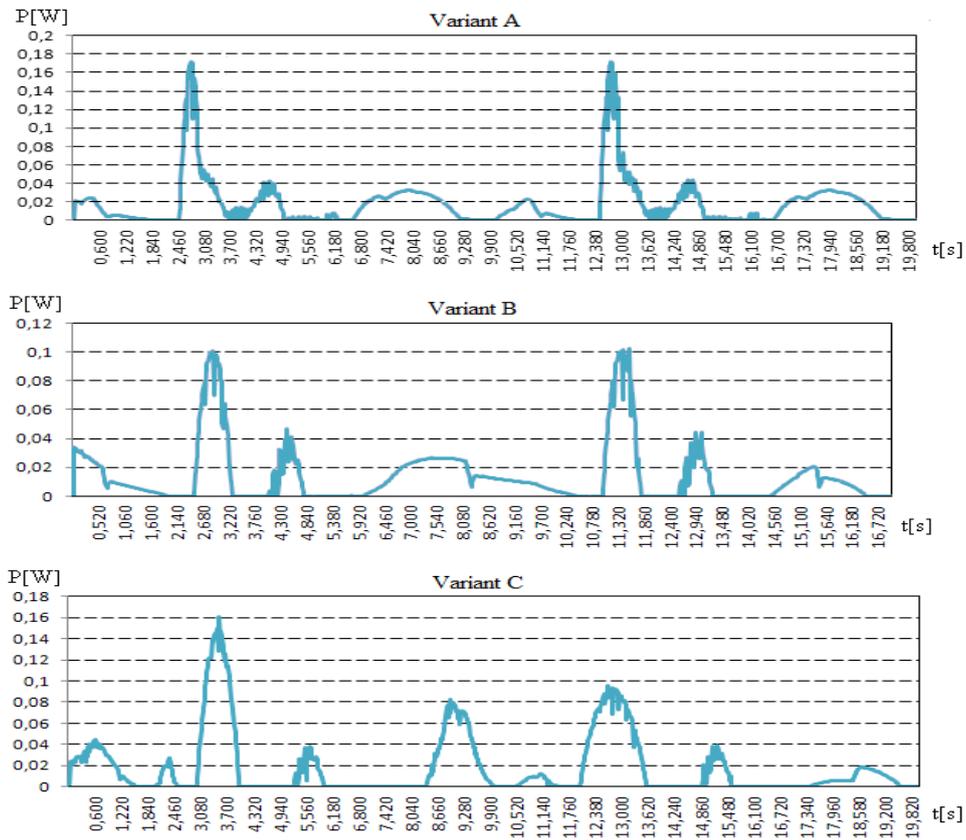


Figure 11. Power consumption of designed variants

Integration of these dependencies in time shows that power consumption of designed variants are approximately equal (variant A = 0.358 Ws; variant B = 0.235 Ws; variant C = 0.351 Ws). All mentioned power consumption is only informative, because efficiencies of used actuators are neglected.

### 4. Self-locking Stability

Very important criterion is self-locking of robot body in situation, when robot staying on one place. Figure 12 shows loss of stability of variant A, because power supply is turned off.

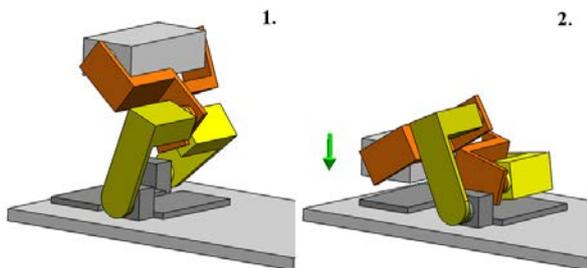


Figure 12. Variant A loss stability (falling down) when power supply is turned off

Holding of stability for variant A is possible only in case of continually excitation of used actuators. However, this requires a lot of energy consumption. For this reason this variant A can be rejected for another robot design.

Variants B and C contains linear actuators, which have screw transmission of power. The used linear actuators have holding force 43 N, which defines maximum load of these actuators.

### 5. Ability of Obstacle Crossing

Step is very frequently occurred obstacle. Simulation of step crossing has been executed. Variant C is able to cross the highest step without loss of stability Figure 13.

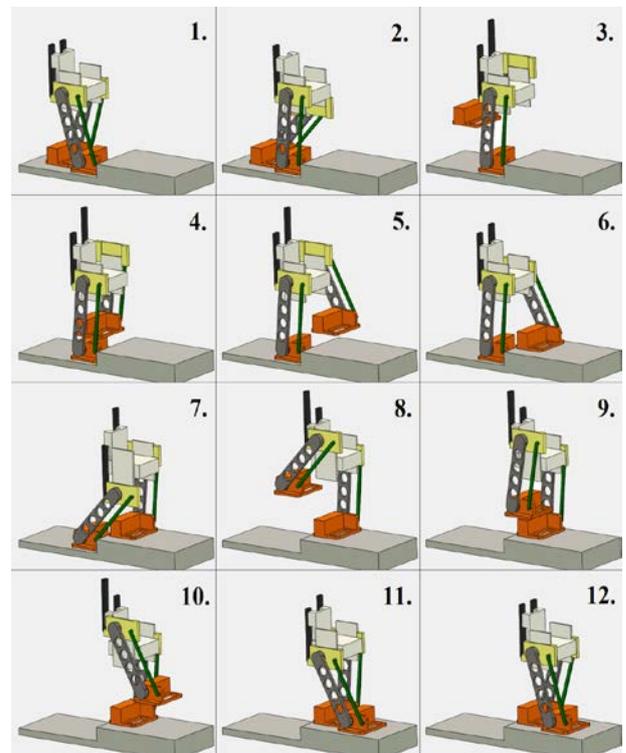


Figure 13. Variant C walking across the step

The variant C has been selected for final robot design, because of its best results in simulation of step crossing.

## 6. Rotation of the Robot

Proposed variant C has been designed for straight walking in forward or backward direction. Rotation of the robot can be realized through the rotation servomechanism placed in foot [Figure 14](#).

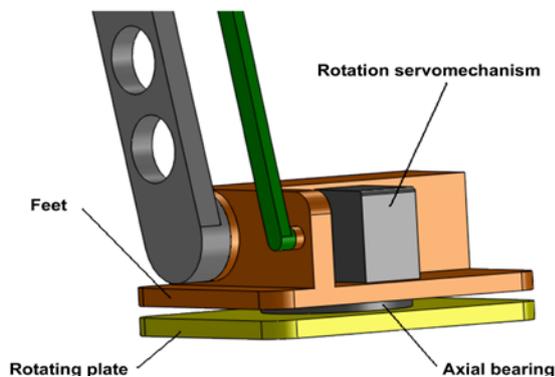


Figure 14. Rotation of Variant C

## 7. Conclusion

On the base of mentioned evaluations, variant C has been selected as best design from proposed variants. The aim was to design the two legged robot with minimum actuators and low power consumption with respecting of robot stability. Another important aim was to find solution with stabilized base plate because of the using of navigation and obstacle sensors and CCD camera for teleoperator remote vision. This property is presented as main novelty in comparing with other existing solutions.

Next steps include selection of the sensors for automatic obstacle avoiding. Infrared optic sensors and ultrasonic sensors have been tested for this purpose.

It is necessary also to sense angle of rotation (position) and torque (force) of the actuators for obstacle (e.g. step) crossing.

Navigation sensor as accelerometer and gyroscope or inertial measurement unit is planned for identifying of the actual robot position and path planning. Gyroscope can be used for stabilizing of the base plate.

Next planes assume the using of the robotic hand for handling with objects.

This robot has been designed as didactic tool at Mechatronic study program at the Faculty of Mechanical Engineering, Technical University of Kosice. Students will practice on this model. Mechatronics is multidisciplinary scientific area and training and exercises should be realized very practically. Everything what students learn at lectures is possible to try at exercises with working on didactic models. They can also attend of competition as RobotChallenge or Istrobot. Didactic models help to prepare our students better for practice in real word [\[12-27\]](#).

## Acknowledgement

This paper is the result of the project implementation: Research of modules for intelligent robotic systems (ITMS: 26220220141) supported by the Research & Development Operational Programme funded by the ERDF.

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