

## **PRESENTATION OF A NEW BIPED ROBOT “ROTTTO”**

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The paper deals with designing and developing a biped robot for research purposes. Robot's mechanical structure, drives and sensor system are described hereunder in details. The development framework of anthropomorphous robot is also presented.

### **1. Introduction**

During the last several years many researchers devote themselves to the tasks how to develop the efficient robot prototypes and their control system. The paper deals with designing and developing a biped robot based on experience of the RobotsLab group. The RobotsLab group is a team of young researchers at the University of Magdeburg co-operating with Fraunhofer Institute Magdeburg IFF. Scientific interests of the group are in the area of robotic, especially in such fields as intelligent and adaptive motion control, optimization and adaption of mechanic and electronic construction of complex mechanisms with many degrees of freedoms, planning complex robot tasks and motion trajectory and so on.

### **2. Mechanical construction of biped robot “ROTTTO”**

The main purpose of biped robot constructions is to develop mobile robot to be able to solve following research tasks:

- research and investigation of the low-cost energy gaits (ballistic walking is one of the possible gaits),
- development and research of the methods of force/impedance control of robot foots during contact with the ground,

- investigation of dynamical walking and methods of robot's body stabilization during walking.

To perform above requirements a biped robot "ROTTTO" (see Figure 1) has been designed and constructed. The kinematical construction of robot is shown on Figure 1 (right). The robot has been constructed to provide more than 15 Degree Of Freedom (DOF) similar to what human being provides. Suggested robot's construction is characterized by modular structure using linear drive systems in each joint. Bearing structures of the robot are fabricated from carbon material and connected to each other with optimized milled-out aluminum constructions. The aluminum-carbon construction reduces the weight of robot and, at the same time provides sufficient robustness.

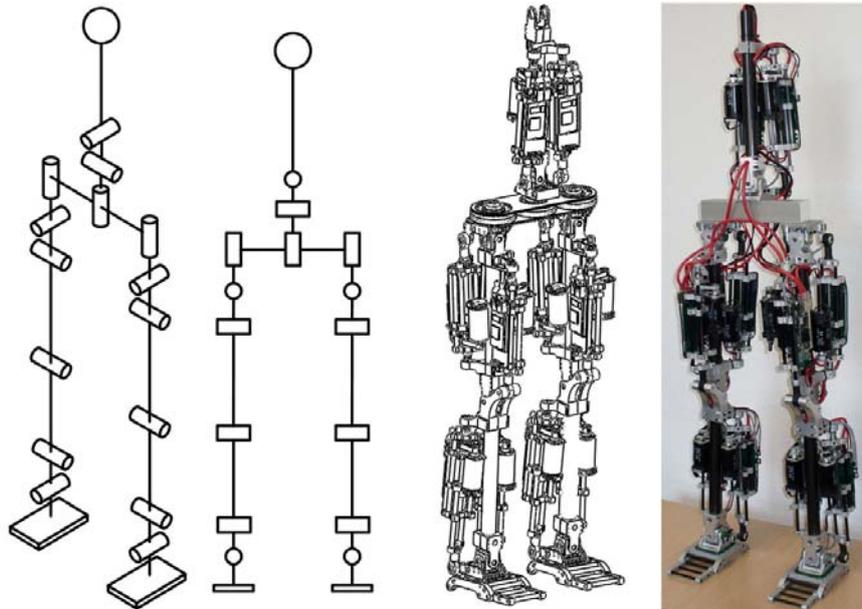


Figure 1. Kinematic structure (left); CAD construction (center); real biped robot "ROTTTO" (right).

The construction of the "hip's" (Figure 2 left) and the "ankle's" (Figure 2 right) joints are implemented in parallel kinematic. Two linear drives actuate the corresponding 2-DOF using the connecting rods and the ball joint. The synchronous and the asynchronous motions of the drives produce the corresponding motion relative to one or another DOF in the joint. It should be pointed out, that such construction ensures the double rotation moment on the two rotation axis.

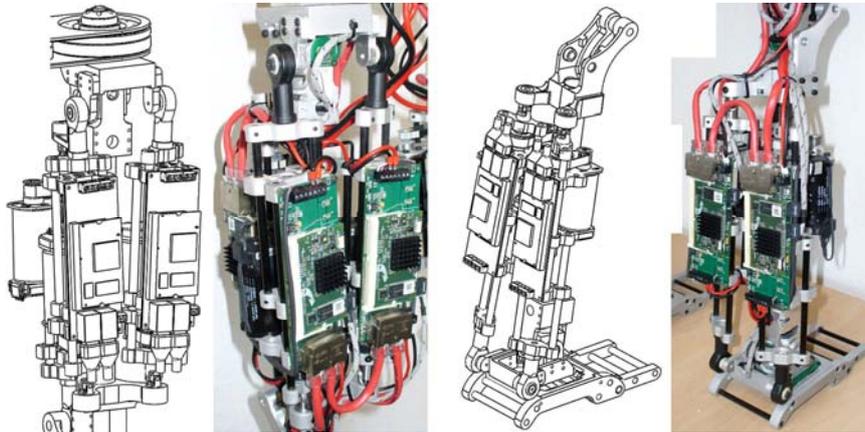


Figure 2. Construction of the “hip’s” joint (left); construction of the “ankle’s” joint (right).

### 3. Actuators of biped robot “ROTTTO”

The actuators of the biped robot “ROTTTO” are implemented as linear drives (Figure 3). The brushless EC-motor drives the ball screw using the belt transmission with a reduction ratio of two. The linear motion of the ball screw’s nut is realized by carbon sticks which are at the same time the direction guide. There is an incremental position sensor on the motor axis. For the safety purpose, two limit switches are installed. The on-board electronics collect all the data from sensors and accomplish current’s control loop of EC-motor. The nominal produced force of such actuator is 128 N with a nominal speed of 0,64 m/s, but the maximal produced force is 400 N and the maximal velocity is 0,72 m/s. It should be pointed out, that the maximal values of the actuator force and speed can’t be reached at the same time.

The complete integration in one module of the motor, the gear, the sensors and the electronic offers the following advantages:

- reduced volume of actuator;
- better dynamic properties;
- higher power density;
- better efficiency;
- using of EC-motor and the modular structure of drive provides better reliability as well as the integrated diagnose and observation functionality.

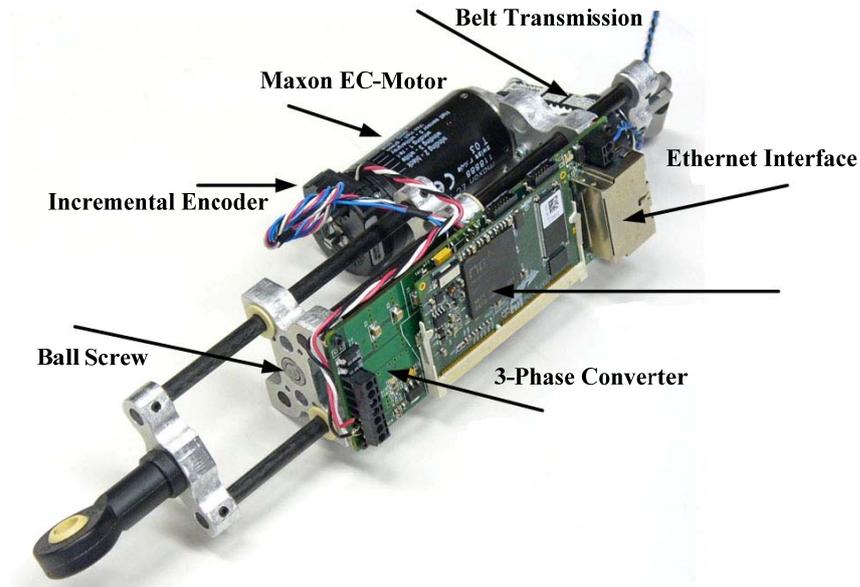


Figure 3. Linear actuator of biped robot "ROTTA".

#### 4. Sensors of biped robot "ROTTA"

The sensor system of the robot consists of components that are standard for mobile robots and that makes it possible to achieve autonomous robot functions in an environment. It includes:

- absolute magnetic encoder installed in each robot joint;
- incremental position sensor, two current sensors and two limit switches installed in each of the actuator module;
- six-component force sensor mounted in each leg's shank;
- high precision tri-axis inertial sensor installed on the robot body.

Designed force sensor provides measurement of forces in wider range in order to comply with the requirements on measurement and control of the support reactions during the dynamical walking. The maximal allowed vertical force is 400N. The maximal values of tangential and lateral forces are chosen up to 300N. The developed sensor is shown on Figure 4. The force sensor (Figure 4) is of "cross" form and consists of four radial beams (1) which connect the robust central flange (2) with the outer flange (3). The positions of eight strain gauges

that are used for the calculation of the reaction forces and torques are determined using the FEM analyze of the force sensor. The results of the FEM analyze is shown on the Figure 5. Usage of the strain gauges is the most widely-known method of the experimental measurement of material tension. The active resistance of the strain gauge is changed with the changing of the material tension. Changing of active resistance of the strain gauge can be easy measured by the Wheatstone bridge. The whole mechanical construction of the force sensor is also optimized according to FEM results.

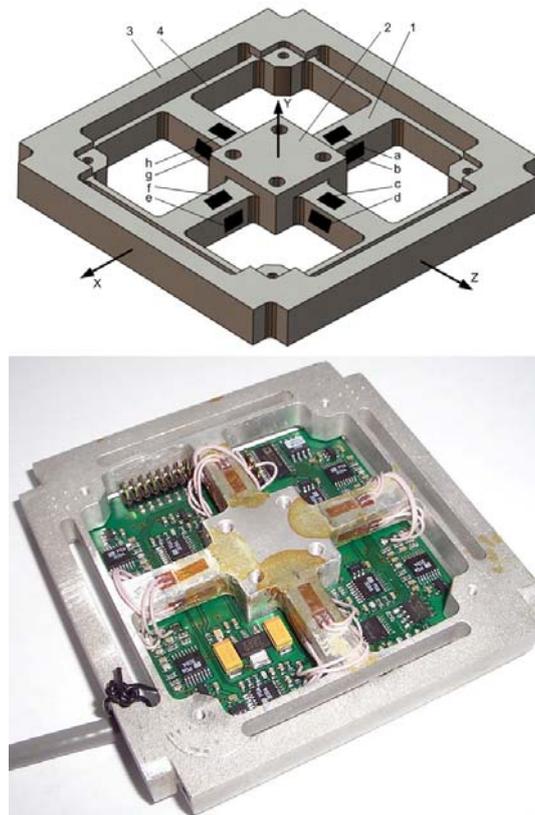


Figure 4. Six-component force sensor of biped robot "ROTTA": CAD model (top); real force sensor (bottom).

During the motion the radial beams are being deformed by the external forces as well as the external torques applied to the central flange of the sensor (Figure 5). These deformations are measured by the strain gauges on all radial beams. The

recalculation measured data from the strain gauges or, to be more correct from the Wheatstone bridges, is described in [6]. The recalculation consists of two stages. First stage is calculation of the sensor (material) stiffness and the second one – sensitivity of the sensor [6].

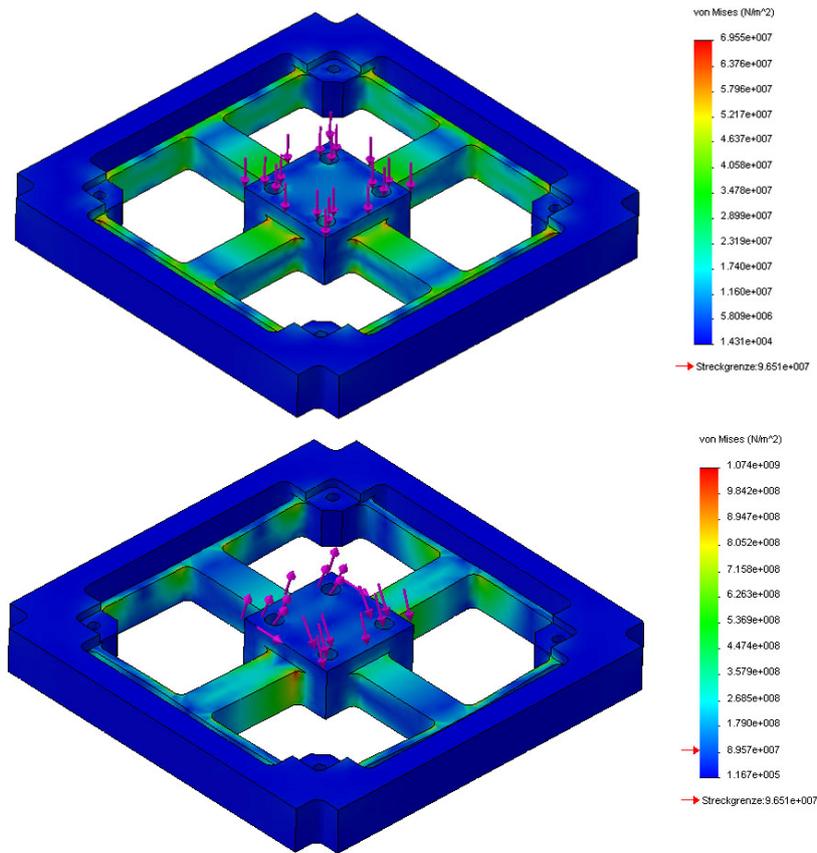


Figure 5. FEM analyze of the developed six-component force sensor.

After large number of experiments on the sensor, the characteristic of the force sensor is defined. The experiments are carried out on trial stand. The force sensor is loaded with the precise weights, so to say with external forces and torques. Obtained results are used for evaluation of accuracy, resolution and other properties of the sensor. The characteristic of the force sensor is shown in the Table 1.

Table 1. Characteristic of the force sensor.

	$F_x, F_z$	$F_y$	$M_x, M_z$	$M_y$
Resolution, [bit]	12	12	12	12
Accuracy, [N], [Nm]	0,29	0,39	0,098	0,1
Measurement range, [N], [Nm]	$\pm 300$	$\pm 400$	$\pm 10$	$\pm 20$
Resettability, [%]	$< 80$	$< 80$	$< 80$	$< 80$

Experimental results obtained during the force sensor test are shown on the Figure 6. The top picture shows the raw information received from all measurement channels of the force sensor. The left bottom picture shows the recalculated resulting values of the torques applied on the sensor. The right one shows the recalculated resulting values of the forces. Obtained results prove quite sufficient accuracy and good resettability of sensor.

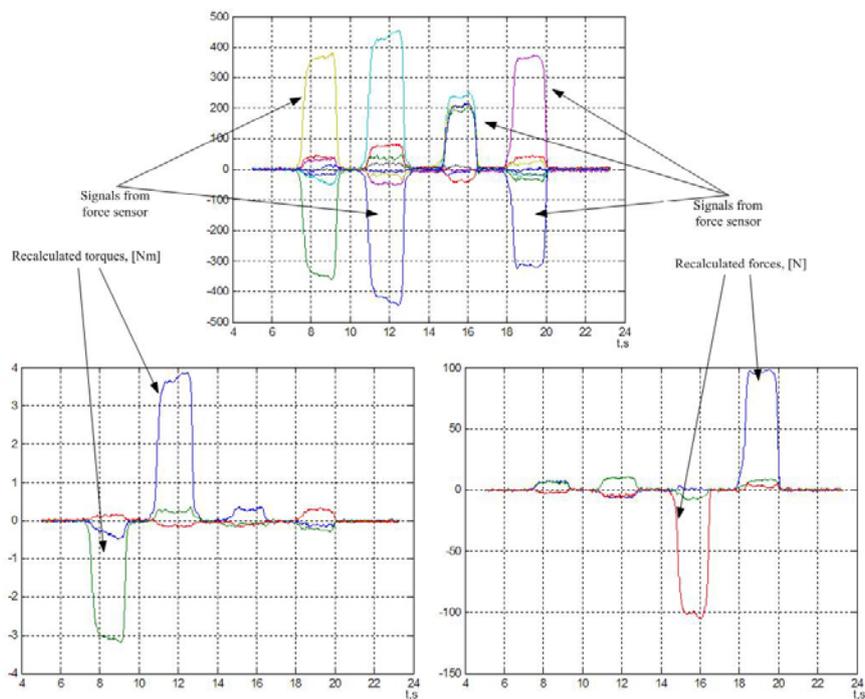


Figure 6. Experimental results of the force sensor under the different loads.

## 5. Conclusion

New biped robot “ROTTO”’s construction as well as the sensor system have been successfully developed. The numbers of requirements such as construction’s modularity, robot’s expansibility, easy manufacturing as well as the numbers of control requirements have been performed. The robot has enough sensors on board, provides fast and safe communication between the robot electronics and the control computer and is able to solve various locomotion as well as the intelligent tasks.

## References

1. <http://www.uni-magdeburg.de/ieat/robotslab>
2. Vukobratovic M., Borovac B., Surla D., Stokic D., Scientific Fundamentals of Robotics. Vol.7, “Biped Locomotion: Dynamics, Stability, Control and Applications”, Springer-Verlag, Berlin, 1990
3. Löffler, K.: Dynamik und Regelung einer zweibeinigen Laufmaschine, Fortschrittberichte VDI, Reihe 8. Nr. 1094.,Düsseldorf: VDI-Verlag, 2006
4. Gienger, M.: Entwurf und Realisierung einer zweibeinigen Laufmaschine, Fortschrittberichte VDI, Reihe 1. Nr. 378.,Düsseldorf: VDI-Verlag, 2005
5. <http://www.hilscher.com> Hilscher GmbH, Hattersheim, Germany
6. MIT Leg Lab: <http://www.ai.mit.edu/projects/leglab> , Stand 2008
7. Gorinevsky D.M., Formalsky A.M., Schneider A. Yu. Force Control of Robotics Systems. CRC Press, Boca Raton, Florida, 2000
8. Hirai, K., Hirose, M., Haikawa, Y., Takenaka, T.: The Development of Honda Humanoid Robot, IEEE Int. Conference on Robotics and Automation, 1998
9. M. Hirose, Y. Haikawa, T. Takenaka, and K. Hirai: Development of Humanoid Robot ASIMO, in IEEE/RSJ Int. Conference on Intelligent Robots and Systems (IROS) – Maui, Hawaii, 2001
10. Löffler K., Gienger M., Pfeiffer F.: Sensor and Control Design of a Dynamically Stable Biped Robot. Proc. IEEE Int. Conf. Robotics and Automation, Taipei, Taiwan, September, 2003