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DESIGN OF THE FRAME FOR AUTONOMOUS MOBILE ROBOT WITH ACKERMAN PLATFORM

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Abstract: *This paper describes the design of the frame and power system of autonomous mobile robot intended to operate as an information portal, or an electronic hostess for indoor environment. The main goal is the construction of rigid and stable chassis considering sufficient proportions and low weight, considering other demands, such as low power consumption, robust safety precautions, construction ergonomics and sufficient space for all necessary equipment. On the contrary to commonly used differential chassis for indoor robots, the Ackerman type of chassis was chosen with additional swinging rear axle feature added, resulting in ability to overcome common indoor obstacles while keeping the stability and low power consumption.*

Keywords: ***Mobile robot, Ackerman steering.***

1. Introduction

When designing mobile robot, there are several concepts of chassis available (Campion, 1996; Iagnemma, 2000; Furukawa). Each approach has specific features that make it preferable for certain operating conditions and expected performance of the designed vehicle under these conditions. In indoor environment the majority of the robots use differential steering chassis due to its maneuverability (Caracciolo, 1999). However when prolonged operational time is required, the energy efficiency demands favor Ackerman steering even with the cost of limited maneuverability resulting in more complex motion planners due to nonholonomic constraints.

This paper describes the design of the chassis for autonomous mobile robot Advee, developed by Bender Robotics s.r.o in cooperation with Faculty of Mechanical Engineering, Brno University of Technology. Advee is the device that purveys information in many ways from audiovisual form to printed documents. It operates as a mobile information portal which is able to orient in space, detect obstacles and avoid physical contact with persons filling the space around it. The platform is intended to operate indoor, while capable of overcoming minor obstacles common in such an environment. When using Ackerman steering, the suspension system is required to keep all the wheels on ground, lowering the rigidity in vertical direction. Such behavior is unacceptable for presentation robots. To overcome this problem, the suspension system is replaced by rear swinging axle, allowing to overcome minor obstacles while keeping the robot rigid in vertical direction.

2. Platform description

Advee is 80 kg heavy four-wheeled robot with overall dimensions of 1100 x 660 x 1600 mm. The platform consists of three parts where the front part represents the main body, in the rear part the actuator with control unit is embedded and the upper part positions electronic equipment into proper location important for its function as the touch screen and the printer output are. Fig. 1 shows the configuration of chassis.

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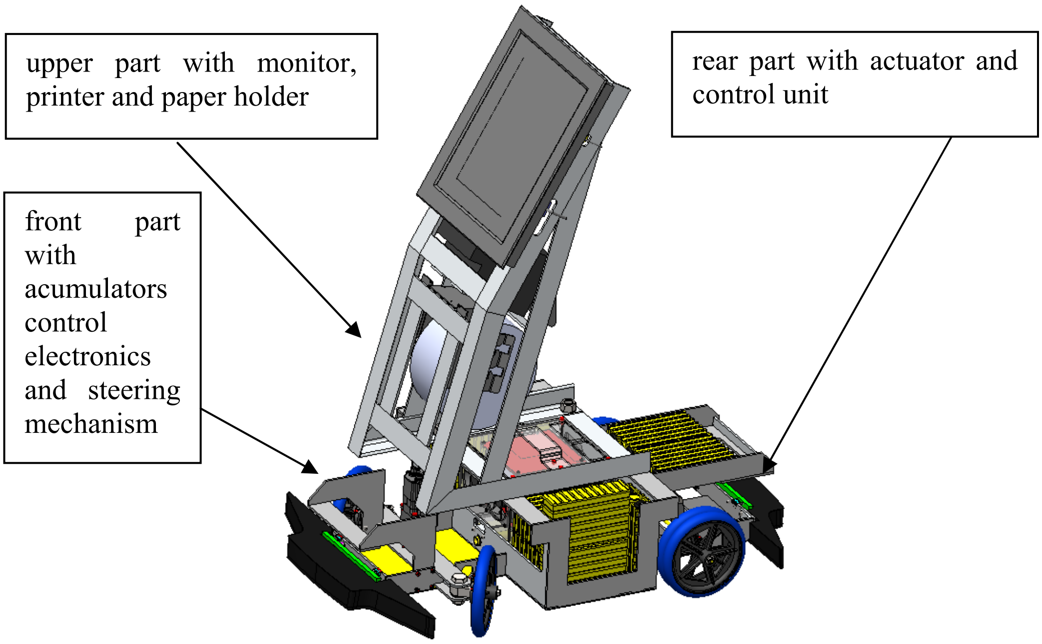


Fig. 1: Advee concept.

Mechanical concept of Advee takes into consideration the weight and position of all equipment of the robot. The loading on each axle is divided approximately in 1:1 ratio, which positively influences the riding qualities. To ensure continuous contact of rear wheels with the floor even while crossing the obstacles the rear swinging axle is utilized. Rear part is rotary embedded in the front part to avoid the slippage of the actuated wheel. This solution increases the load on the front wheels, but keeps the upper part of the robot rigid.

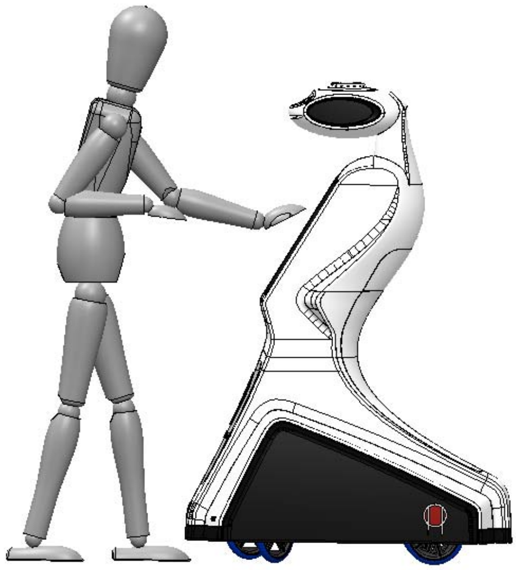


Fig. 2: Study of touch screen position.

The height of the platform results from optimal position of touch screen for comfortable manipulation. The proper angle and height of the monitor was determined on the 1:1 simplified model. Fig. 2 gives an impression of relative position of average height adult human and the monitor placed on the frame.

Wheel gauge of the platform is a compromise between the stability of the robot and its trafficability. The value of wheel gauge was initially proposed based on static stability calculations, allowing up to 15 degrees deflection from vertical axis. The dynamic stability of the chassis was tested on the physical model (Bender II platform with additional upper frame simulating the mass of the Advee equipment (Hrbáček, 2010)).

3. Frame construction description

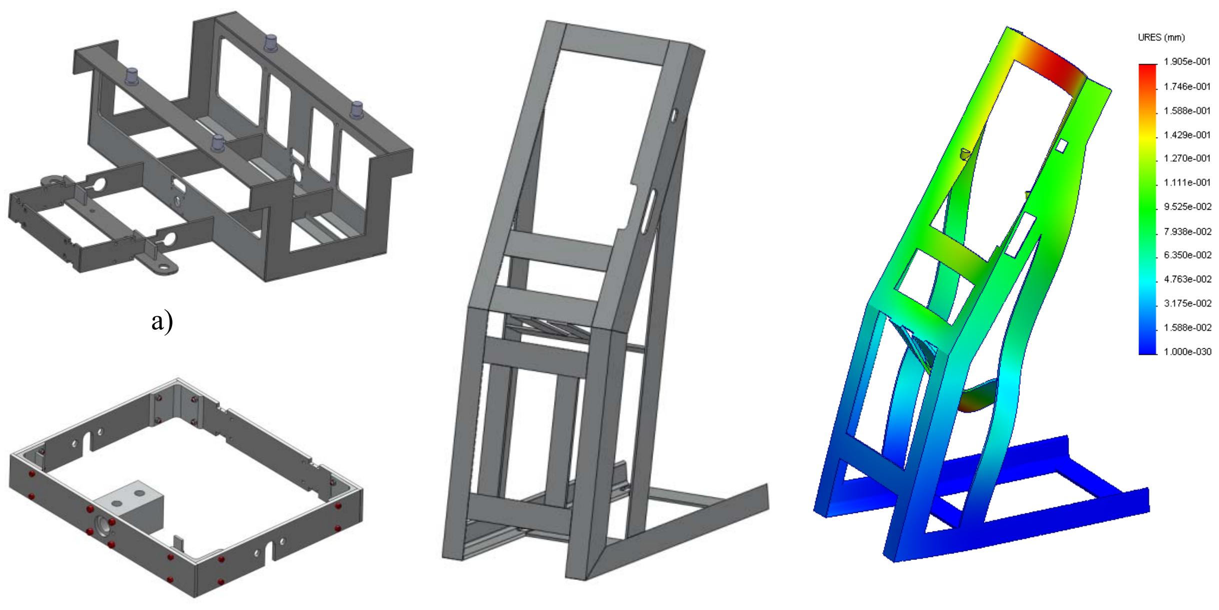
The frame represents the base of the mobile robot construction. The main task while designing the proper frame concept is the weight, proportion and rigidity optimization, which can be achieved by appropriate material selection and mechanical design.

Material significantly affects weight and rigidity of the construction. Aluminum is evaluated for its durability combined with small density. These properties make it the optimal material for mobile robots where the robustness and low weight are most demanded attributes.

Considering large proportions of the robot the manufacture of the frame from monolith intermediate would be expensive and complicated. Therefore the welded assembly of aluminum profile is used. Although the connection by welds is undetectable and imprecise, there are lesser demands to geometric complexity of components and total weight is decreased by absence of connecting parts. The geometry of the chassis follows the dimensions and shape of the equipment, that is predefined (accumulators, touch screen, printer).

Fig. 3 shows all three parts of the frame. Utilization of rear differential makes the rear part of the robot difficult to assemble and there are also higher demands to accuracy, therefore as the only one is assembled by screw connection.

The stress and strain analysis of the frame was performed using FEM, leading to modifications in upper part of the frame, where even low displacement can cause damage of the outer shell. Modified frame (Fig. 3d) exhibits maximum displacement of 0.13mm, after full static load of the equipment.



b) c) d)

Fig. 3: a) Front part, b) Rear part, c) Upper part, d) Deformation analysis of the upper part.

Mobile robots have to carry numerous amounts of electronics which is connected by cables. Since the first study of mechanical design of the frame the path of the cables must be considered. The chassis of Advee allows connecting passage among all three parts. Between the front and rear part there is enough space designed, as those two parts move towards each other.

Rear swinging axle is realized by separation of the rear part from the rest of the frame. The rear part contains the drive unit, while the front part represents the main construction, to which all others components are assembled. Front and rear parts are connected by torsional shaft allowing them to swing around each other in the maximum relative angle of about 10°. This way the constant contact between rear wheel and surface is ensured even while the platform has to deal with heavy load. Disadvantage of this concept is decrease of stiffness which exhibits by oscillating while passing an obstacle. This problem is solved by torsion spring embedded between moving parts.

4. Actuators design

The selection of the proper actuator reflects in energy consumption and riding qualities of the robot. While designing the power system many conditions must be considered (as for example the weight, maximum speed, type of wheels and the maximum ascent). Based on the calculation comprising all the physical influences the actuator Maxon RE 50 with 24V/200W DC motor, planetary gear (26:1) and incremental sensor been chosen.

The determination of sufficient power of the steering mechanism is difficult task, as the calculation would depend on very precise acquaintance with mechanical model simulation and used friction model, that can vary for different types of surfaces the robot is intended to move on. Therefore the required power was determined on the base of the measurement of forces actions in the testing platform Bender II steering mechanism, adjusted to the wheel load of Advee, resulting in Berger Lahr actuator with planetary gear (40:1). The measurement scheme is shown on Fig. 4. and the torque required on different surfaces is shown at Tab. 1.

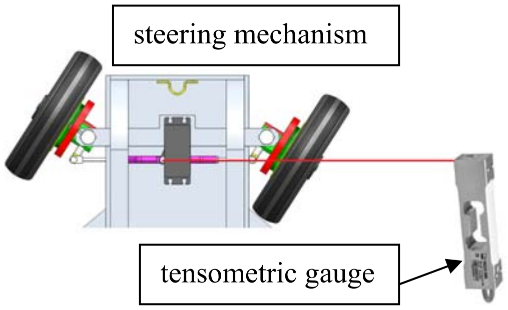


Fig. 4: Scheme of measurement..

Tab. 1: Steering power measurements.

Surface	Force	Torque
Bituminous road	35 N	2.1Nm
Sheet pavement	28 N	1.68Nm
Linoleum	26 N	1.56Nm
Carpet (long pile)	60 N	3.6Nm

5. Conclusions

This paper describes the design of chassis of autonomous mobile robot Advee. Used solution provides energetically efficient and robust robotic platform. The 1600 mm high and 80 kg four wheeled robot offers excellent stability and riding qualities. The concept of Ackerman steering with swinging axle proved superior behavior in indoor environment. Single motor and differential proved to be sufficient while keeping the cost of motion module at reasonable level. Although the use of automotive chassis brings intricacy caused by nature of its motion control in space, the energetic efficiency exceeds all the other concepts utilized in mobile robotics. Thanks to motion efficiency Advee can offer over 8 hours of autonomous service for a single battery charge.

The platform was tested in range of environments. The prototype is currently commercially used and after over 100 hours of operation the mechanical chassis does not exhibit any flaws.

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