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Autonomous mobile robotic system “Sesarma”

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Abstract. The present paper is dedicated to computer modeling of the autonomous mobile robotic system. The review of publications and analogues is performed; the structure diagram and design of the developed robotic system are presented. The search for a robot body concept is carried out; a stage-by-stage process of its three-dimensional modeling is presented. The body lines are created using a high polygonal modeling method. The process of setting and assignment of materials based on polygonal model elements is described. A renderer is selected and light sources are installed, final scenes of scene rendering with robot are shown.

1. Introduction

At present, robotic systems in human life have more actual meaning than ever. In many fields of our life, the robotic systems of different complexity degree are used as assistants. In the majority of cases, robots come to the aid of man to where access for people is impossible or this is connected with defined life and health risks. In many developed countries they conduct investigations on development of the mobile robots of different purpose. At present in the processing field the meaningful results have been achieved connected with creation of the high-power onboard computers, compact executive mechanisms and intelligent sensors. The modern algorithms use high-speed information processing methods when controlling motion, both of single mobile robotic systems and within a group.

In this paper we review the design and carry out computer modeling of the autonomous four-wheel mobile robotic system to solve different tasks. When solving the tasks in the field of the industrial design, the preliminary elaboration and selection of design of the product body are rational. The developed mobile robotic system has a three-level control system and can operate within a group when moving under data incompleteness conditions, in the nondeterministic medium. Let us consider some review of the recent research in this field and the current analogues of the created robotic system.

2. Review of publications

The paper [1] is dedicated to the analysis of the current state of the global trends in the area of creation of the small-size robot support facilities of different assignment. The basic principles and development prospects of mobile mini-robots are highlighted. The paper [2] presents an overview of research in the field of the autonomous mobile robot control. There is a possibility of using the principles of interpretive navigation to improve self-containment of multifunctional mobile robotic systems of radiological “MRK-2” and “RTK-08” surveillance (Research Institute of Robotics and Engineering Cybernetics, Saint-Petersburg).

The article [3] describes the problems of motion control of the mobile robot in the nondeterministic media by the potential field method. The review article [4] presents the analysis of research results in



the field of mobile robot route planning based on the classical and evolutionary approach. The review of the control tasks without centralized coordination on the basis of the various algorithms is investigated in the article [5]. In the book [6] the modern methods of group control of the mobile objects in the uncertain environments are considered. The methods of group control using fuzzy logic and unstable modes are described.

The article [7] describes the main methods related to modular and reconfigurable mobile robotics. Structural modular morphology allows adapting to the unstructured real environment. In comparison with crawler and wheeled robots, the walking robots are more effective when moving along tough terrain. The article [8] considers the kinematic scheme of the executive mechanism of the octopod based on the biological prototype of the crab skeleton.

The aim of the paper [9] is to analyze the current state and development prospects of robotic systems for military purposes. The paper [10] investigates the problematic issues of the development of the autonomous ground-based robotic systems for special purposes for high-precision navigation.

Interaction of the mobile robots within the group is of great practical importance. The paper [11] is dedicated to modeling and analysis of collective biological systems in relation to the behavior of swarm of mobile robots. The paper [12] presents an overview of the work on the robotic research in development of the swarm robotic systems for the real environment. The review of the papers on research of soft robotics with deformable bodies is given in the article [13]. In the papers [14] and [15] the review and prospects of research on the process of production of sensors and applications for soft biomimetical fish robots are considered.

We also note some analogue use of the developed mobile robotic system. Four-wheeled mini robot Nerva LG (weighing 4 kg) of the company “Nexter Robotics” (France) is designed for remote surveillance of the environment [16]. Multipurpose compact FirstLook robots (weighing 2.4 kg), SUGV (13.5 kg), PackBot (weighing 18 kg) are developed by iRobot company (USA) for the tasks of countering self-made explosive devices and detection of potential hazards during military operation execution [17].

Throwable multi-purpose mini robots are sufficiently relevant. Mini robot Yule (weighing 0.6 kg) is developed by the Central research institute of Robotics and Engineering Cybernetics (Russia) [18]. It can conduct discreet remote audio-video observance in the field and urban infrastructure conditions. Throwable three-wheeled mini robot Pocketboot (0.85 kg) of Novatig (Switzerland) is designed for remote surveillance of the environment [17].

Small-scale four wheeled robot MTGR (weighing 9.4 kg) is developed by Roboteam (Israel) and designed for mine clearance of explosive objects, surveillance, detection of chemical, bacteriological or radiation contamination. The compact robot on the tracked chassis DAGU (weighing 10 kg) is developed by General Robotics (Israel) and designed for surveillance, assault operations. Walking robot CLOOS (weighing 69.4 kg) is manufactured by Autonomous Solutions Inc. company (USA) to search for mines and inspection of hazardous materials [17].

The mobile robotic systems “Cross-country vehicle TMZ” (weighing 35 kg) and “Varan” (weighing 185 kg) designed for remote visual surveillance, search for and disposal of explosive devices, are developed by the Research Institute of Special Engineering of Moscow state technical university named after N.E. Bauman [19]. Robotic platform Warrior (weighing 226.8 kg), iRobot (USA) are designed to move potentially hazardous objects, clearing the path, extinguishing fire or surveillance [18]. The multifunctional robotic crawler system “Platform-M” (weighing 800 kg) developed by the Scientific Research Institute of Technology “Progress” is designed for surveillance and combat operations [17].

3. Robot structure

The structure of the developed robotic system in the assembly is shown in Figure 1. The base platform of the system has the following characteristics: length – 360 mm, width – 225 mm, height – 200 mm, continuous work time without recharging – 1 hour, maximum motion speed – 10 km/hour, minimum speed – 1cm/sec, weight – 3 kg.

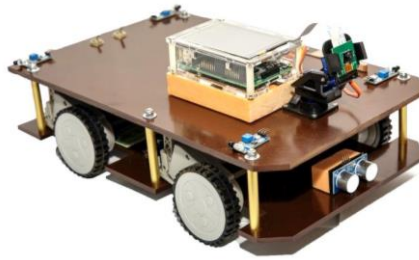


Figure 1. The structure of the mobile robotic system.

The block diagram of the mobile robotic system with a three-level control system is shown in Figure 2 [20, 21]. The lower level consists of four wheels, electric motors with encoders, motor power drivers and servo control microcontrollers. Microcontrollers function as adaptive proportional-integral-differential controllers Arduino Nano.

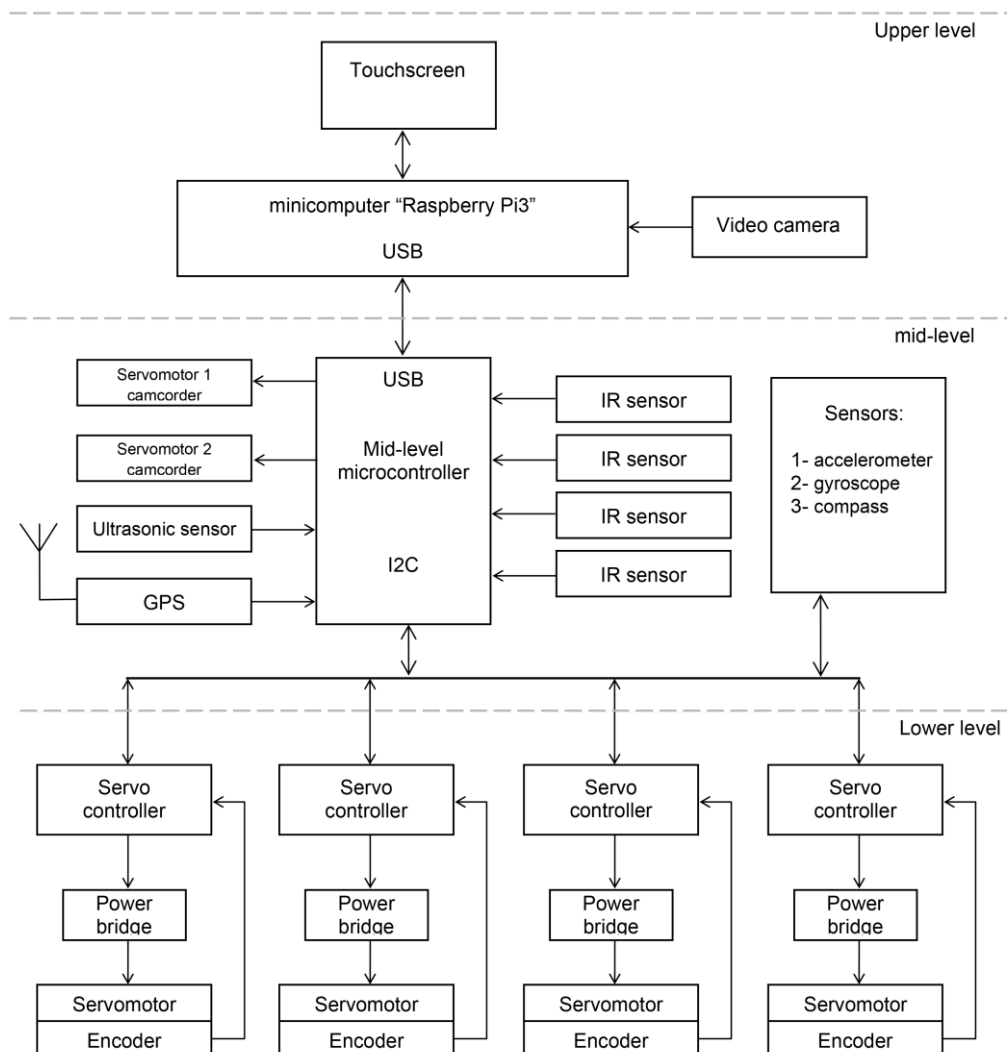


Figure 2. The block diagram of the mobile robotic system.

The mid-level microcontroller collects and pre-processes environmental information. The following units are connected to the mid-level microcontroller: an accelerometer; a gyroscope; a compass; four infrared distance sensors; an ultrasonic distance sensor and a GPS sensor. At this level, there are also directing servo drives and cameras that are guided by this microcontroller.

The upper level controls the robot and is based on the Raspberry PI3 minicomputer [22]. The minicomputer implements data transfer protocols: Bluetooth, Ethernet, Wi-Fi. The robot camera gives the possibility of implementing artificial vision; all the levels are interconnected by data communications protocols. The mid-level microcontroller is associated with the upper-level microcomputer by the UART protocol (Universal asynchronous receiver/transmitter). This connection allows avoiding malfunctions at different signal levels. The mid-level and lower-level microcontrollers are interconnected by protocol I2C or TWI; this provides minimum data exchange rate.

4. Modeling concept

Let us proceed to development of the computer three-dimensional model of the robotic system and its outer body lines based on the operating conditions. It is necessary to develop variants of the robot body with the upper platform, where the cargo compartment or the arm of the manipulator will be located. The authors have experience in solving industrial design tasks in the field of mechanical engineering and hydroaviation [23, 24].

First, the schematic structural design of the robot's internal platform is carried out on the basis of the overall dimensions and layout design of the components. Further, in the process of searching for the lines of the outer body of the robot, the associative series of biological prototypes was analyzed, some visual solutions were found [25, 26]. Figure 3 shows variants of the visual search based on the arthropod crayfish and crabs. Later on, the set of sketches will determine the style and color scheme of the future product; red mangrove crab *Sesarma* [27, 28] was chosen as a biological prototype. The crab is a representative of arthropods, a class of crustaceans, has 5 pairs of limbs, the front pair has the form of powerful claws. With the loss of one of them, a new claw overgrows, frequently in nature claws are asymmetric. Because of the overall claws, crabs usually move backwards or sideways.

5. Modeling stages

As a result of the stage-by-stage search, taking into account functionality and aesthetics, one of the variants of the volumetric solution meeting most closely the requirements of the technical specification was worked out (Figure 4).



Figure 3. Variants of visual searching for the body lines.

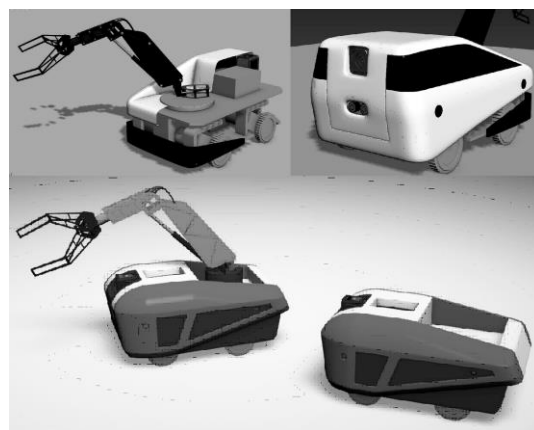


Figure 4. Three-dimensional search models of the future body.

The body shall be not only aesthetic, but also practical, preventing ingress of the foreign objects and dust into the inner part of the robot. In addition to the above tasks, the body plays the role of the bearer of identity – corporate identity. The body contains visual information about the developer's company;

it can be painted in corporate colors or acquire camouflage color for some special tasks.

The final version of the body lines is dictated by the modern trends in the transport design and ergonomics. Plastic material is used for the body; gloss coating of the material can be replaced by more practical – matte one. The body structure consists of four parts (Figure 5), the central part forms the frontal part of the body and the platform for the manipulator. Two symmetrical halves on the right and left, have the holes for infrared sensors, the rear lower cover closes down the wheels partly.

At the next development stage, a three-dimensional computer model of the body prototype is created. The variety of software products of two-dimensional and three-dimensional graphics allows implementing various design ideas. First, you need to have two-dimensional drawings, diagrams or photos, which are then exported to the universal formats for further processing in three-dimensional space. DWG is one of these formats, we will use the graphics system 3ds Max [29, 30] as a program of three-dimensional modeling. This software product along with other methods allows creating models through High-Poly (high polygonal) modeling. Due to this the lines of the model will not have the faceted view, but a more streamlined shape.

To create a realistic model of the body in the graphic system 3ds Max, the projections, cuts and sections of the future body are used. The standard scheme of High-Poly modeling consists of gradual increasing in the level of detail of the three-dimensional object:

- the first level is basic and represents the approximate shape of the object;
- the base shape is refined typically by adding chamfers and curves at the second level;
- the third level is the final one, distinct detail of the object is performed through application of smoothing plugins.

Further refinement and fine tuning of the body model is made, at the final stage TurboSmooth modifier is used for the final smoothing (Figure 6).

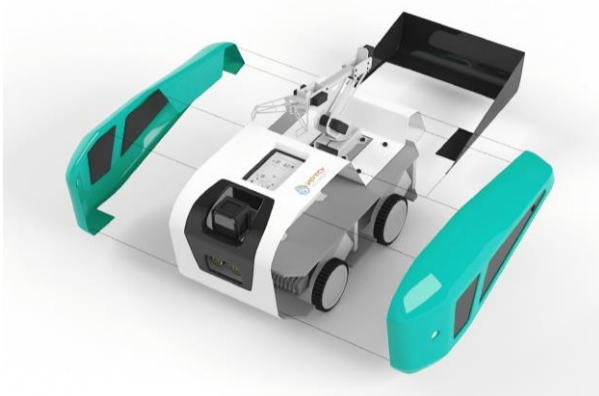


Figure 5. The robot body assembly scheme.

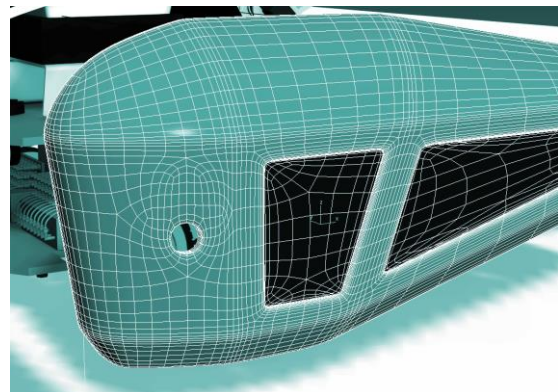


Figure 6. The high polygonal grid of the body model.

6. Creation and assignment of materials

Further it is necessary to configure the model to create and apply materials. The methods of creating the materials are determined by the subsequent method of scene rendering. The external rendering unit V-Ray from ChaosGroup will be applied to create realistic rendering in the 3ds Max graphics system. This software package contains many parameters allowing controlling the quality of scene rendering and countdown time. The renderer requires the use and configuration of its own set of V-RayMtl materials, which is different from standard materials.

The material setting is carried out in the basic parameters roll of the material editor. When creating a scene with a robot model, several materials with characteristic parameters were applied. Before assigning the materials, we divide the three-dimensional model into the component elements. Then we create the material to simulate plastic and apply it to the appropriate elements.

Let us consider the main parameters of the created material (Figure 7):

- diffuse color is the color of the object surface. You can choose a solid color or set a texture. In our case, we choose the one without texture, imitating white plastic;
- parameter Reflection (Reflection) adjusts the reflective properties of the material. If 100% black is selected in this window, then the surface of the material is not reflected. If it is white, then the surface becomes fully reflective. All intermediate gray values determine the intensity of the reflection;
- the parameter of reflection and refraction Fresnel IOR (index of refraction) is the Fresnel coefficient that depends on the refraction of light rays.

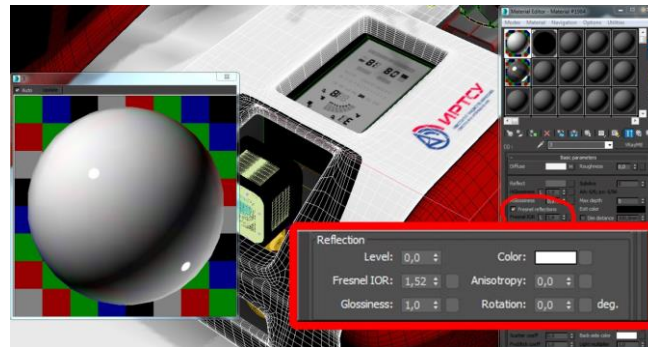


Figure 7. The dialog box for setting of the material reflection.

The rest of the materials in this scene are set up in the same way. Separately it is worth noting the setting of the material for the inscriptions on the robot body. In this case, the texture based on the bitmap image of the company logo is applied as diffuse color in the Diffuse roll. Assignment of materials occurs at the level of polygons with preliminary allocation of the corresponding group.

7. Lighting installation and rendering

Graphic modeling systems use two types of lighting: artificial (lamps) and natural (sky and sun light). The most realistic renderings are obtained by combining them; this lighting option is called mixed or combined.

The used renderer V-Ray is quite popular software different from the analogues quality and speed. For stage we will simulate studio lighting (artificial). Therefore, the model of the robot is placed on the base without a clear horizon line (the base plane smoothly passes into the background plane). Then we get a soft background on which the created robot model is located (Figure 8).

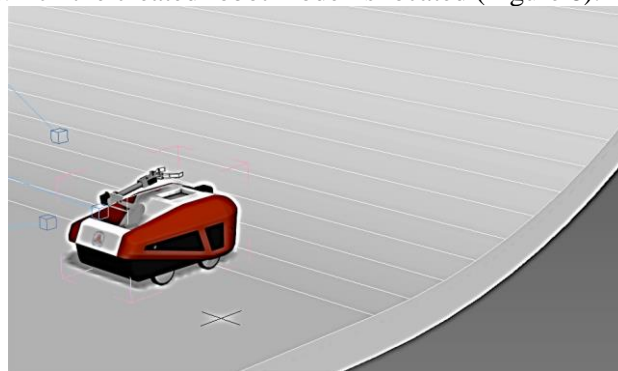


Figure 8. Creating the surrounding objects in the scene before rendering.

Modeling of the artificial lighting is carried out by installing of two equivalent V-Ray-Light sources from the opposite sides. This allows getting glare on the model surface necessary for realistic rendering. To adjust the shooting angle, a camera is installed; the results of the final scene rendering with the robot model are shown in Figure 9.

8. Conclusion

In conclusion, it may be noted that in this paper the design was described and computer modeling of the developed mobile robotic system was carried out. It can be used for both industrial and educational purposes. As a result of modeling, an aesthetic and functional case was created, which emphasizes the main purpose of this product. The process of preliminary prototyping enables the rational selection and justification of the design of the robotic system before its production.



Figure 9. The final rendering of the scene.

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