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Interaction of a Humanoid Robot Nao with a Non-Humanoid Walking Robot

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Key Words: Robot; sonar.

Abstract*. The paper considers a novel algorithm for performing joint tasks between a humanoid robot NAO and a low-budget (Low-Cost) walking robot Big Foot. The specific construction of Big Foot allows movement by walking, change of direction and overcoming obstacles by using only two engines. The principle of movement of Big Foot is presented and the parameters, which determine the step and velocity of movement, are discussed. NAO robot sets the beginning of task execution and controls reaching the target position by the non-humanoid robot. NAO sonars are employed for this purpose. The non-humanoid robot Big Foot is controlled remotely by a human. The information on the timing of the executed movements and the reaching of the target is collected in several ways by using the sensors of NAO and Big Foot. The obtained results are analysed. Possibilities for application of the proposed algorithm are discussed.*

Introduction

In our previous studies the non-humanoid robot Âig Foot was used in scenarios for educational games of children with special needs [1]. We designed scenarios with NAO humanoid robot for learning based on imitation and exercises for improvement of the motor activity of children with special needs [1]. The positive results of these studies made us look for further development of the scenarios by implementing dynamic interaction between the two robots and the human.

NAO robot is equipped with sonars, which are being used for obstacle detection. A comparative estimation of the precision of distance measurement between NAO sonars and camera, on the one hand, and external devices, on the other, is made in [2]. The authors of the study obtained the lowest error in the case of measurement via depth sensor Asus Xtion Pro Live in comparison with all other methods.

Applications of sonars for localization of mobile robots are proposed in [3]. The authors found out that, after using a filter, the measurement precision increases. The sonars of NAO for detection of obstacles and their avoidance are described in [4]. In this study the sensors of NAO robot are used as well as a depth sensor ASUS Xtion Pro for distance estimation aiming at detection and signalling in case there is a dangerous situation lake a fallen person in home environment. In [5] the high importance of the sonars is emphasised in interactive tasks for collision avoidance between mobile robots. In the study a simulation is made for collision avoidance between two NAO robots during robo-soccer competitions. The employed sonars are of range from 0.15 to 0.75 [m].

Materials and Methods

In the present study a humanoid robot NÀÎ V5 is used, equipped with two ultrasonic sensors (sonars), each consisting of an emitter and receiver with frequency: 40 kHz, resolution: 0.01 [m] - 0.04 [m], range: 0.2 [m]–0.8 [m]. Under 0.2 [m] there is no information about the distance and the robot is aware only of the presence of an object. Above 0.8 [m] the precision of the measurement is low. Effective cone: 60° [6].

Mobile robots have improved by using different methods and means for locomotion [7]. In [8-9] an original idea is presented for a Low-Cost walking robot, realized via 3D printer. The robot Big Foot (*figure 1a*) consists of a round base (1), on top of which the body is mounted (2), equipped with two motors, allowing it to move by walking and to turn around. Its movement preserves static stability due to the big round base (2) and the two feet (4). The vertical rotation R_1 allows the robot to turn when the feet are elevated (4). The plane mechanism for walking consists of 3 units (2), (3), (4) with lengths a_1, a_2, a_3, respectively, interconnected with rotating links (*figure 1b*). The feet (4) preserve constant orientation relative to the round base (1) by means of a gear (5). The rotation R_2 actuates the walking mechanism. The robot is described in more detail in [8]. The 3D printed model of the robot is currently being developed by equipping with sensors and improving its control system.

Three infrared sensors are attached GP2Y0D810 (7), capable of detecting and obstacle in front of the robot and one RGB sensor (6) for colour (*figure 1a*).

The walking of the Big Foot robot is performed in two phases: 1 – fixed feet (4) and rotating arm (3), body (2) and base (1); 2 – fixed base (1) and rotating (3) and (4). Theoretically, the step S of movement of the body (2) can be inferred from *figure 1b.*

$$S = 2\sqrt{a_2^2 - (a_3 - a_1)^2} \quad (1)$$

under condition $a_1 \geq a_2 + a_3$ and $a_3 \geq a_2 + a_1$.

After the body moves as a result of the rotation of the arm (3) at angle φ_1, the body of the robot stays fixed for a certain time until the feet move – rotation of arm (3) at angle φ_2 (*figure 1c*). The two angles are complementary to a full circle $\varphi_1 + \varphi_2 = 2\pi$ [rad]. The velocity V_x of the robot movement within one horizontal step is not constant. It can be determined from the expression:

(2) $V_x = \omega_1 a_2 \cos(\varphi)$,

where ω_1 is the angle velocity of the body of the robot at fixed feet, and φ is the current angle of rotation at fixed feet. The formula (2) does not account for the dynamic effects at the engine start as well as the impact load upon contact of the base (1) with the ground.

We consider the joint task execution by two robots and a human under the following conditions:

The aim of the Big Foot robot is to move from the initial position to the target position in cases when there can be obstacles to overcome or avoid. For example, in *figure 2*.

1. Scenario: NAO pronounces a voice command Start! to initiate the control of the walking robot and determines the moment Finish! when the walking robot has overcome the obstacle (executed task). The execution time is recorded.

2. During task execution Big Foot sends information about reaching intermediate positions and the target by the colour sensor, thus increasing the reliability of the robot control.

We have conducted experiments in the following conditions:

NAO robot is in position of the "Rest" [6] – *figure 2*. The distance from the sonars of NAO to the walking robot is in the range 0.28-0.30 [m]. The length of the obstacle is 0.255 [m]. To the body of the walking robot a reflector is attached with dimensions 0.12 x 0.12 [m], located at height 0.28 [m]. Depending on the sonar range 3 zones can be determined: *figure 1*.

Left, including the initial position of the walking robot and the blue step (*figure 2*); Middle, being in the range of both sonars when stepping completely on the yellow step; Right, in the range of the red step and the finishing position.

In the specific conditions, based on expressions (1), (2) and from the experiments, it became evident that one step of Big Foot is performed in 4 seconds. This gave us the reason to include in the control of NAO measuring the distance every 4 seconds. The dimensions of Big Foot are a_1 = 0.018 [m], a_2 = 0.056 [m], a_3 = 0.065 [m]. The step S from formula (1) is estimated at 0.06 [m].

Results

A number of experiments were conducted with the given parameters. Results from the measurements of the sonars about the distance to the walking robot are shown on *figure 3*. At the initial position, *figure 2,* Big Foot is in the range of the left sonar at a distance 0.28 [m] and is not in the range of the right sonar. The first four values show that Big Foot is in the left zone and during the third measurement in 12 seconds the right sonar gives 2.5 [m], which is a value outside the range of the sonar. The next four values show that Big Foot is in the middle zone. The values of the sonar are in the range 0.3-0.5 [m], meaning that the robot is in front of both sonars. The final three values show that with going away from the left sonar, the robot enters the range of the right sonar. At the 40th second of the measurement, a value 0.6 [m] is generated, which does not correspond to the actual distance. The software of the walking robot calculates correctly the robot movement over the coloured steps in the case of contrasting colours. The time for which the robot moves over the obstacle can be determined by the indications of the sonars, which are generated every 4 seconds. In this specific example this takes place in 44 seconds.

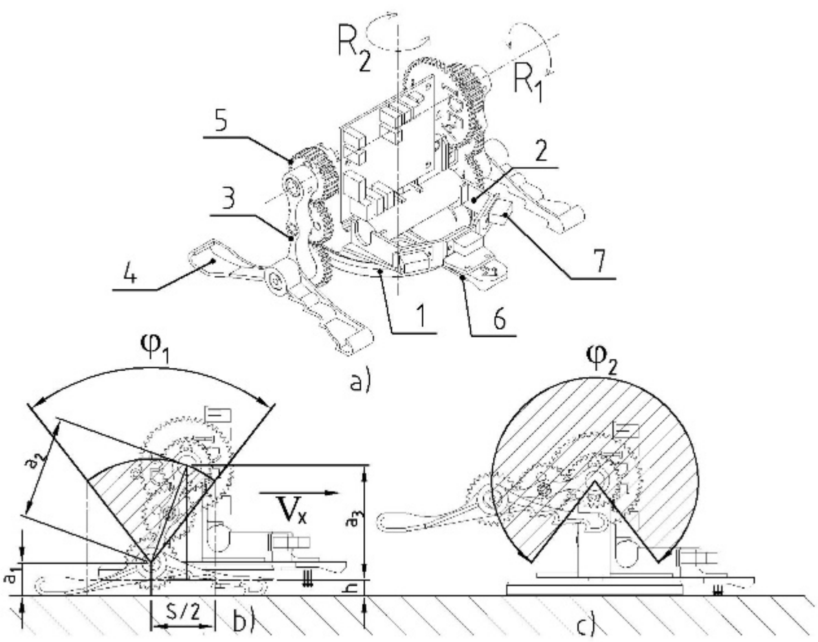

Figure 1. Big Foot robot and the main parameters for determination of the walking step

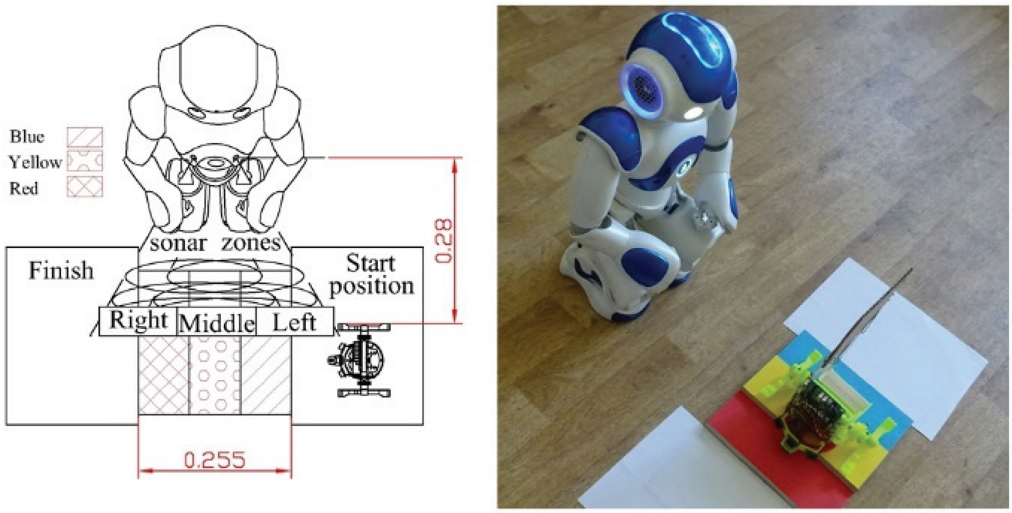

Figure 2. Experiment and scheme of the location of the robots

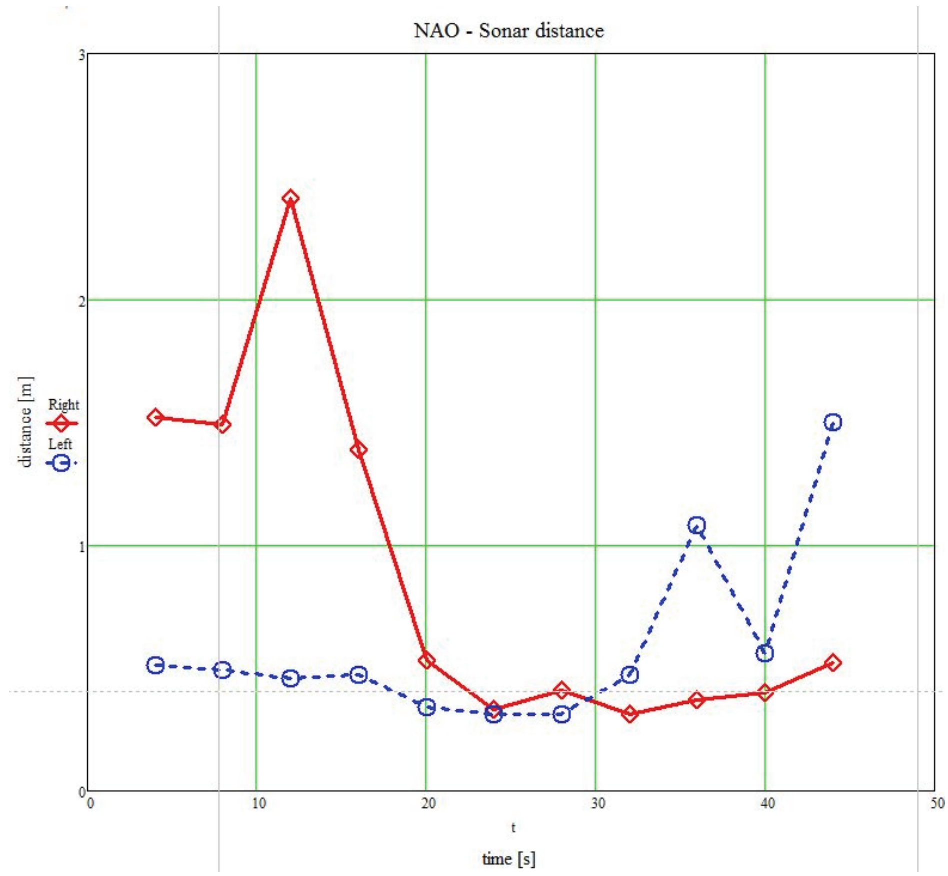

Figure 3. A sample from the measurement with left and right sonars recorded during the experiment

Discussion

In the chart in *figure 3* measurement errors of the sonars can be seen; a substantial peak is seen at measurement three in comparison with the first, second and fourth, although there is no object in front of the right sonar at that time. The minimum error is obtained when the robot is located in the middle zone in front of both sonars.

We have noticed that the precise detection of the distance from the sonars to the object depends on its size and reflective surface. From our trials we have determined that sonars of the present model detect well the distance to big stationary objects. Big error results in cases of objects of small area and moving objects. In search for solution to this problem we used an additional accessory “reflector” to reflect the ultrasound waves, which helped the sonars of NAO to detect the walking robot and to determine its movement direction. The walking robot moves at a low pace, which is favourable for the experiment. High precision measurements for distance detection to smaller in size objects can be achieved by using of additional external devices such as depth sensors [2-4] or laser scanner [10]. The information about the location of Big Foot is complemented by its colour sensor, depending also on the areas of the coloured feet and the step of the robot, *figure 2*.

Conclusion

The conducted experiments with the two robots aim at developing of structured games, where robots can evaluate objective parameters in task execution. The time and precision of the positioning of Big Foot are computed and this information is obtained from two independent sensor systems, which increases the reliability of the results. The data can be easily recorded, processed, analysed and transmitted remotely. The "reflector" improves the results only in the aspect of determining the zone, where the walking robot is located – left, middle or right. This work can be used in future studies of dynamic interactions of two robots and a human.

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