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ADVANCES IN MECHANICAL STRUCTURE AND MOTION OF SMALL SIZED SELF-GOVERNING FOOTBALLER ROBOTS

Felipe Alencar de Oliveira
Márcio Valério de Araujo
UFRN – Universidade Federal do Rio Grande doNorte
eng.ofelipe@gmail.com; mva_acari@yahoo.com.br.

Abstract. *Robots competitions are being disseminated around the world. Among several categories, there is IEEE Very Small Size where the robots use moving wheels, are autonomous and have maximum dimension of 75mm. The robots have a unique colorful mark, allowing the view system to distinguish each robot partner or opponent, ball and field. They have embedded electronics and communicate via radio to a computer, responsible for vision system's graphs processing and send control signals based on the programed strategy. The robots are impelled by two wheels driven differentially, each one has its own motor which is activated with specific rotation speed independently, by electric motors. Although, it is usual to appear an inconvenient shaking around an imaginary rolling axis – as it happens on a seesaw – because of the two wheels configuration. This paper intends to solve the problem creating a unique and steady plan for support the robot. To this end, two designs are proposed, one with three supports and other with four supports. Changing the configuration of the wheels implies modifying the kinematic model, which is necessary to control the robot. To verify the efficiency of the designs will be made experiments on speed, force and level of shaking.*

Keywords: *autonomous, moving robot, IEEE Very Small Size, seesaw effect, shaking.*

1. ROBOT SOCCER

The robot soccer challenge was introduced in order to increase development in the field of robotics and artificial intelligence. It has several categories, among them the Very Small Size, which follows the rules defined by IEEE. Each team competes with three robots in field with maximum dimensions of a cube of 75 mm of edge (Silva, 2010). The robots must be self-governing, autonomous, it means, once the match has started, no human must control their action. More details can be found in IEEE, 2008. Thus it is required a computational control that perceives what is going on and acts favorably to the team objective.

The control is based on a previously set strategy and its objective is to find the best path to access the goalpost, diverting the opponents. The biggest part of these proceedings is realized outside the robot. In this way, a computer recovers the images taken by a camera suspended in the air and treats them, identifying the marks of the field, the top surface of the robots and the ball. Concluding this image processing, the computer recognizes the position and orientation of each robot, ball and goalpost (Xiaovvei Han, 2004). Now the computer inserts the parameters acquired to the strategy algorithms that will decide the action of each robot. It will be calculated the new position of the robots and sent, to the receiver on the robot circuit board, the speed values of each wheel, via radio. All of this is made in real time, live (Chung-Hsien Kuo, 2006). Figure 1 shows us the robots placed during a match of Very Small category.

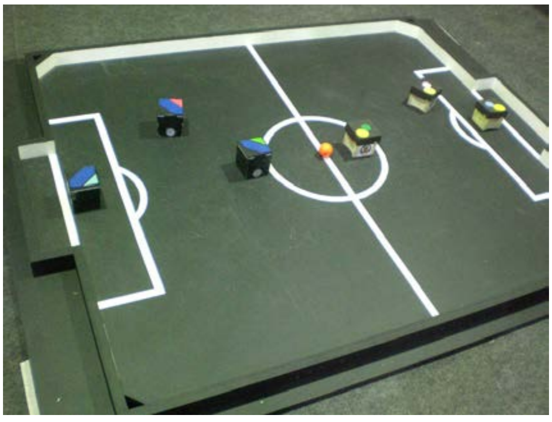

Figure 1.Robots soccer match.

1.1 Purpose

An inconvenience that happens on robots provided with two wheels is a shaking movement, which looks like the movement of a seesaw. It occurs because of the lack of a support plane, due to its construction on two wheels, that is, it is not created a single and stable plane for the robot. The movement happens when the robot is accelerated in opposite direction of its current speed, this is a fact linked to the group's inertia. To create a static plane it is needed at least three points. It can be perceived that the distance between the robots bottom and the floor is an important parameter. If it is too short the robot will get stuck, if it is too high it will shake a lot. It is possible to see how the shaking movement occurs in the Figure 2.

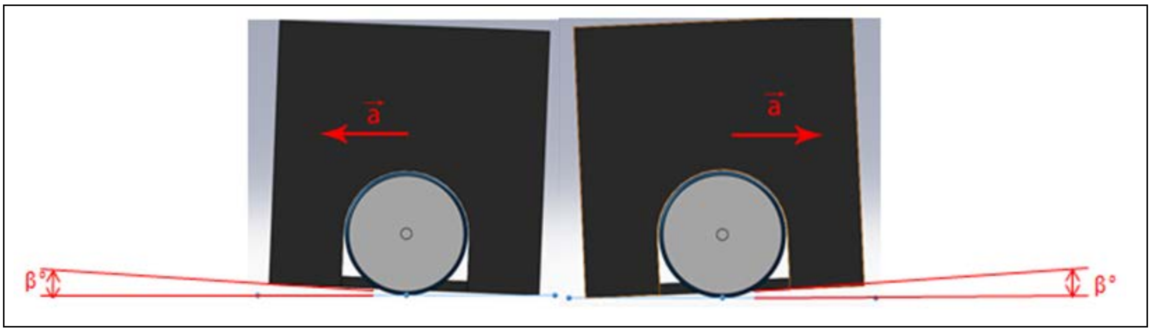

Figure 2. Seesaw movement while accelerating.

The shaking movement confuses mainly the robot control as it generates a delay between the command and the execution, which confuses the computer processing. The problem also influences in the running action, because deviates considerably the calculated robot path. Besides, it is known that some electronics components suffer under influence of mechanical shocks. Until this work, the solution adopted was to fasten shims to the robots bottoms but they wear and returned the problem. Now the idea is to use supports which move along with the robot, avoiding most of the friction with ground.

2. DESIGN

This section will describe each prototype: the first is the standard, the second has a support plane defined with three points of support and the last one is defined with four points of support. Robot Hum (shown in figure 3 – I) is the simplest, very robust. Project Tripod (Figure 3 – II) is a modification that brings the wheels backwards and adds a support in the front. The Tetrapod robot (Figure 3 – III) is a second modification and has 4 wheels.

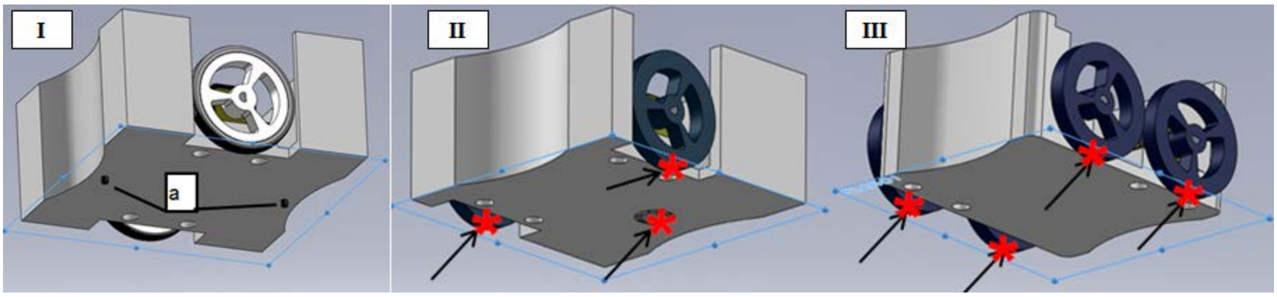

Figure 3. Project "Hum" (I), Project "Tripode" (II) and Project "Tetrapode" (III).

2.1 Hum

This is the simpler robot that will be tested as a standard. It is made of ABS polymer using a 3D printer, it has lithium polymer batteries and, to avoid the shaking movement, Allen screws were fastened through the robot bottom. It can be seen this robot in Figure 3 – I, where the letter "a" points to the Allen screws mentioned before.

2.2 Tripode

The prototype has three points of support, two of them are the wheels and the third one is a ball caster. This last one will be driven, i.e. it will have a passive movement. The wheels are dislocated backwards. This will confer a static and unique plane of support. At the Figure 3 – II is possible to observe the Tripode and three points of support (marked with asterisk), that create a stable plane.

2.3 Tetrapode

The prototype has four supports, they are two driven wheels and two conducted wheels. Each similar pair is assembled diagonally. The shafts housings for the shafts of conducted wheels are manufactured on the robot base with the same rigid ABS polymer, ensuring good durability for the part. This concept also reduces the number of components and facilitates the alignment on the assembly. Figure 3 – III shows the project Tetrapode and points four supports (marked with asterisks).

3. EXPERIMENTS AND RESULTS

To determine the effectiveness of the prototypes concerning the evaluated problem and conservation or improvement of kinematic and kinetic standards of earlier robots, experiments were performed. Divided into four tests, two kinematic: non loaded and loaded speed test and two kinetic: Strength test and the Shaking test.

3.1 No-load speed test and Loaded speed test

No-load speed test was performed to verify relative speeds of each PWM (Pulse-Width Modulation – technique used to control power sent to motors, so to speak) considering the robot free of the effects of friction and inertia. The motors were activated without load and, with assistance of a digital optical tachometer, the reached rotation was registered, as see in Figure 4.

Figure 4. Measure of RPM of wheel with tachometer, showing value of 195,1 RPM.

The Loaded speed test was performed activating PWM equally in both wheels and with the robot bearing its own weight. The result is the linear motion, later and uniform linear motion and this is from where the data was treated to calculate speed. The modified software also collects all data related to position an orientation on the Cartesian plane, this can be seen in Figure 5. Also uniform motion is highlighted.

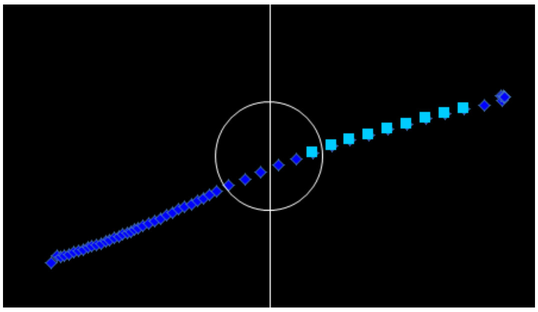

Figure 5. Registered points of Tripod in PWM of 100%, they form the followed path on that test.

Table 1 is a comparative made between the speeds reached by each robot according to the PWM of activation. It is divided by tests series, Speeds without loading (with tachometer) and Speeds with load (robots own weight).

Table 1. Comparative between real speeds.

	Speeds (no load) - (m/s)			Speeds (loaded) - (m/s)		
PWM	**Hum**	**Tripode**	**Tetrapode**	**Hum**	**Tripode**	**Tetrapode**
0,1	0	0	0	0	0	0
0,2	0,1	0,1	0,11	0	0	0,04
0,3	0,21	0,21	0,23	0,2	0,09	0,17
0,4	0,32	0,32	0,34	0,32	0,2	0,31
0,5	0,43	0,43	0,45	0,39	0,34	0,43
0,6	0,53	0,53	0,56	0,56	0,45	0,54
0,7	0,64	0,64	0,67	0,66	0,57	0,65
0,8	0,75	0,75	0,78	0,75	0,69	0,77
0,9	0,85	0,84	0,87	0,87	0,82	0,87
1	0,92	0,93	0,94	0,97	0,92	0,89

Even if the motors are standardized, there are differences between the electromechanical components manufactured. The linear speed of the wheels fixed to the non-loaded motor shaft was a little above the average for the robot Tetrapode, even the assembly technics, the electronic components and the mechanical being equivalents. Thus one believes that the motors of the third project are slightly more powerful than the other and/or the batteries have absolved bigger electric charge.

Comparing the average speeds with loaded robots between the three projects of robots, Hum has done better in five different PWM, Tetrapode in three and at 90% of power, there was a draw between both. These results, a little bellow of project Tripode and Tetrapode, are due to a higher friction force that both have to overcome. While project Hum has only two little tips (relatively small area) in contact with land, Tetrapode has two shaft housings measuring 3 millimeters of diameter and 8 millimeters of width witch with tribological pair of PTFE-ABS and Tripode has the friction between the ball caster measuring 9 millimeters of diameter and the ball caster housing.

3.2 Force test

To this experiment, a precision scale was fixed to a solid base, with big area and weight, so the scale was hold orthogonal to the desk (as seen in Figure 6). The motors of the robot were activated with the same PWM, the measure shown at the scale is directly proportional to the force applied by the robot.

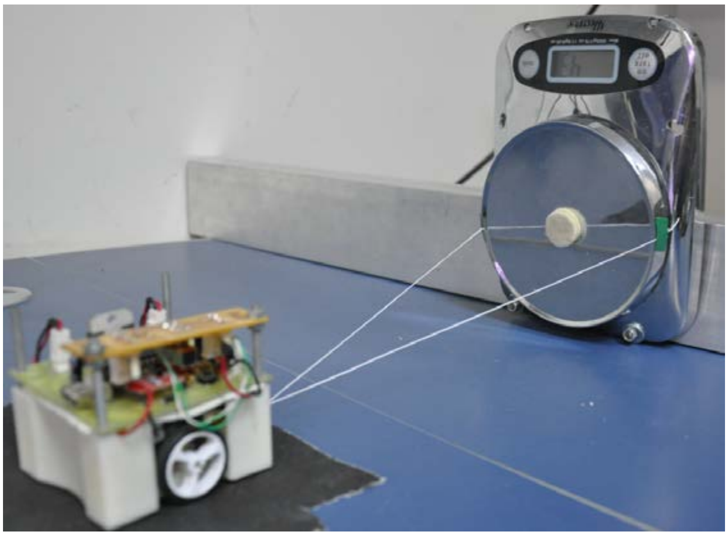

Figure 6. Force test with robot. The scale indicates 43 grams.

It can be seen at Table 2 the average forces found for all the robots in each PWM. At PWM of 70%, the force values kept around an average of 1,80N. An explanation to the fact is that on this PWM level, the wheels starts to spin on kinetic friction (wheels were sliding), with intensity smaller than static friction.

Table 2. Comparatives between forces.

Forces (N)			
PWM	Hum	Tripode	Tetrapode
0,1	0,00	0,00	0,00
0,2	0,00	0,00	0,41
0,3	0,36	0,42	0,63
0,4	0,80	0,85	0,69
0,5	1,14	0,98	0,98
0,6	1,50	1,56	1,45
0,7	1,68	1,91	1,80
0,8	1,88	1,30	1,29
0,9	1,98	1,28	1,21
1,0	1,95	1,27	1,21

Robot Hum showed dissonant results in higher PWM, because even with kinetic friction prevailing, forces values kept increasing, which do not fits reality. In general, Tripode has higher values in force results, this is because both project Hum and project Tetrapode when pulling the string, the robots posterior part slightly raised, decreasing normal force end consequently the friction force between tires and land.

This fact (raising of a side of the base) must be taken into account the selecting robots to a match, because there are, sometimes, some ball disputes, the opponent robots push themselves and if a robot reduces its contact to the land, and consequently its force, it will also loose the dispute.

3.3 Shaking tests

To verify if the projects succeed to overcome the shaking problem, the motors were activated with equal PWM, but during the test, the signals were inverted. The reversion of direction of wheel spinning was sufficient to cause a sudden change of movement of the robots and generate shake.

Table 3Table 4 contains the grades and their meaning in each test, the lowest being more efficient, in relation to the ideal (no shaking at all).

Table 3. Grades given to levels of shaking.

Grades	**Level of shakiness**
3	High
2	Medium
1	Low
0	None

Table 4 is a summary of the evaluation of the robots taking count shaking issue. After the analysis of videos recorded during tests, the grades were assigned.

Table 4. Results of shaking test.

Avg. PWM	**Hum**	**Tripode**	**Tetrapode**
30%	2	2	1
50%	2	2	1
80%	3	3	2

As for the shaking level, it can be seen in the results shown at Table 4 that Tetrapode performed excellent results and these results could be better with improvement in manufacture of shafts and preparation of shaft housing, because in the way they were mounted, the robot contained small uneven in one of the wheels, thus it has not a unique stable plane the support itself.

Despite all expectation, the project Tripode has shown movement around a rolling axis, but analyzing closely, its wheels were placed in a region more central than it should, letting a certain volume "uncovered of support" and free to shake (see Figure 7). The figure also shows the only direction in which the shaking movement occurred, on the opposite direction shaking was null. Shaking only occurred in this direction because under this volume there wasn't support which prevented the movement around the rolling axis.

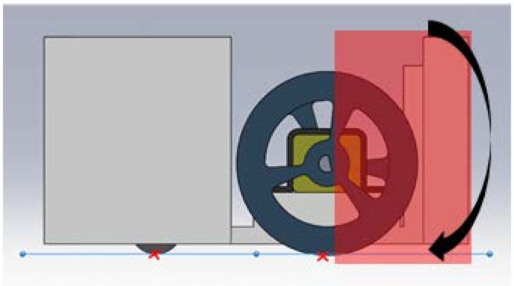

Figure 7. Volume - shade - without support and shaking direction – arrow.

4. FINAL THOUGHTS

Eliminating shaking movement, new robots will be easier to control, also won't have bad connection issues and even won't lose kinetic energy due to shaking.

The robot Hum is simpler than the others, it is easier to manufacture and assemble.

The Tripode project is more stable, theoretically, but it has some complications on the manufacture and assemble steps and if not well-designed may end up with the problem in Figure 8.

Tetrapode is very difficult to manufacture and little deviations can ruin their small parts, also this project, along with Tripode, has a higher cost.

Thus, it is preferred to maintain the use of robot Hum, keeping the settings of the support screws well made.

To repair the deviation in Tripode Project, it is suggested that motors should be displaced to a further position backwards, until the wheels reach the 75mm limit. This will improve bigger support area. Also, it is a recommendable idea to install a metallic ball caster of the same model and, when drawing in CAD software, is important to include holes for the ball caster and its screws.

To improve the robot Tetrapode, it is a good idea to manufacture the shafts for the driven wheels in a lathe, which will ensure a better geometry and dimensional tolerances within accordance with the project requirements.

A second type of Tetrapode could be designed installing one ball caster in each support screw position of project Hum.

There is also an idea of implement an electromechanical kicker, it means, design and assemble a device able to shoot the ball with high force and speed, excluding the need to conduct the ball through goalpost. It is necessary to pay attention to the game rules that forbid that any robot part exceed maximum dimensions.

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