Automatic Guide for Blind Athletes

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Abstract— This paper proposes the introduction of a guide robot in the Paralympics competitions allowing the blind athletes to compete without a person who guides them. The robot is composed by a vehicle which carry a human shape dummy that replace the no-blind person. The robot has a battery which can be charged both from the grid and from a solar panel located in the top of the dummy's head. The wheels speed and torque are provided by two DC motors. At this moment, the mechanical structure and the solar panel harvesting system and a Maximum Power Point Tracking (MPPT) topology are designed. The next stage of the design process are the line tracking and athlete's speed follower systems.

Index Terms—Automated Guide, DC Motors, Electric Vehicle, MPPT, Paralympics, Robot, Solar Panel, Flyback

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I. INTRODUCTION

The blind athletes compete in the Paralympic games running next to a person who guides them. There are some problems related with this way of competing: the first one is the difficulty to find a person who has the same physical characteristics as the competitor and the second one are the illegal contributions of the guide.

The guide must be a professional athlete in order to not penalise the blind athlete performance. In most of the cases the guide is faster than the competitor. Due to this, there are some occasions when the guide pull the blind to run faster helping him to do reach a better position than he actually could. Of course this is illegal, but is hard to judge these actions because the video evidences do not clearly show the actual contribution of the guide.

To solve these problems, and automatic guide robot is proposed to assist the blind athletes and allow them to compete by themselves. Furthermore, the robot will improve the competitive experience of the blind runners. The proposed guide robot is shown in Figure 1.

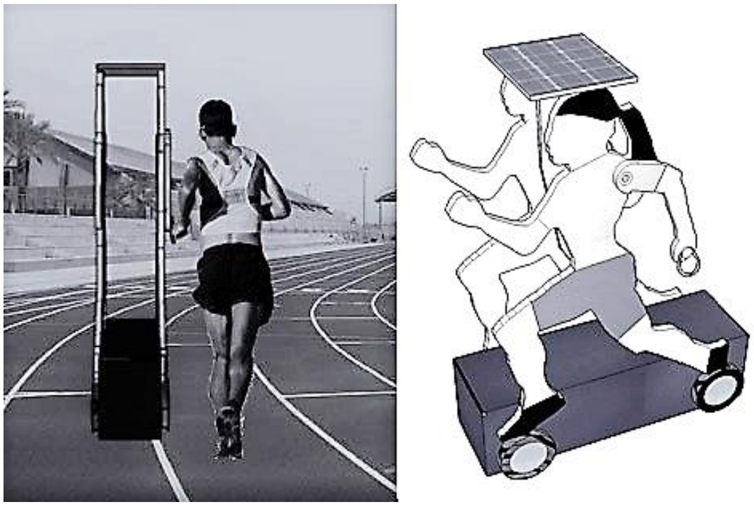


Fig 1. Proposed guide robot

The guide robot is composed by a dummy, the robot itself, where the electronic components are placed, and a solar panel in the top of the dummy's head. In the following sections, the different parts of the robot will be explained and a deeper analysis in the energy harvesting of the panel will be developed.

II. PROPOSED METHODOLGY

The first step in the work is to define the mechanical elements. These elements, such as the dummy material and the external chassis of the robot, are chosen in order to make the robot as lighter as possible.

Once the mechanical elements are chosen, the traction motors are selected with the specifications given by the maximum speed and acceleration than a professional athlete can reach. The parameters has been obtain from Usain Bolt registers [1].

The next step is to select the battery in order to reach enough autonomy to finish an entire day of competition working without charging. The maximum number of races celebrated in a day of Olympic Games was estimated as ten.

In order to charge the battery the robot has two alternatives: an external charger and the solar energy harvesting. The external charger hasn't been designed yet. The solar energy harvesting will be made thought the PV panel using a DC/DC converter as Maximum Power Point Tracker (MPPT).

Once the mechanical and electrical systems are designed, the last step is to design the control system. The line tracking system keep the robot over the white line of the road. Furthermore, the robot follows the speed of the athlete thanks to several sensors placed in the dummy´s lateral.

III. THEORETICAL DESIGN

A. MECHANICAL SYSTEM

The material selected for the dummy´s body was the PUR35 due to its resistance and low density. The weight of the robot taking into account the dimensions, the density of the material and the approximated weight of the battery and the PV panel is 15 Kg. Once the weight is estimated, the forces applied to the robot and the angular speed necessary can be calculated as (1), (2) and (3). The Figure 2 shows the mechanical scheme of the robot.

$$n = \frac{60}{\pi} \cdot \frac{V}{d} \tag{1}$$

$$F_r = -\frac{1}{2} \cdot C_p \cdot A_{transversal} \cdot v^2 \tag{2}$$

$$F_p = m_{vehicle} \cdot a_{max} \tag{3}$$

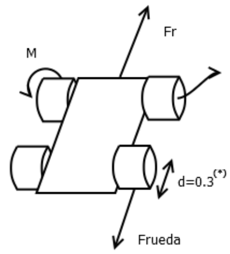


Fig.2. Mechanical scheme of the robot.

Where the maximum speed and acceleration of the robot are the Usain Bolt reached records [1]. With the forces calculated the maximum torque required in the motors is calculated (4).

$$M_{máx} = \frac{F_{máx}}{2} \cdot d \qquad (4)$$

Once the parameters are calculated, the brushless motors are selected attending to the maximum torque and angular speed.

B. POWER SYSTEM

The robot power system is represented in the Figure 3. The power system is composed of several subsystems connected thought a DC link. The motors are connected to the DC link thought an inverter. The battery is connected thought a Double Active Bridge (DAB). It must maintain the DC link voltage constant to its rated value (12 V). The PV panel is connected to the DC link thought a Flyback converter which acts as an MPPT.

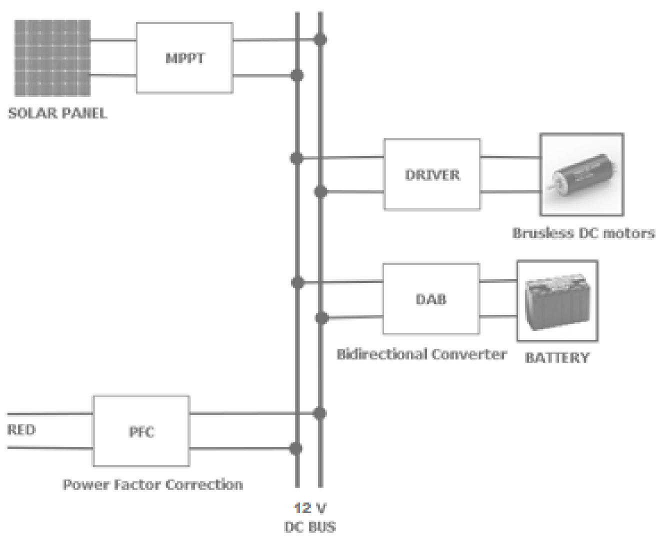
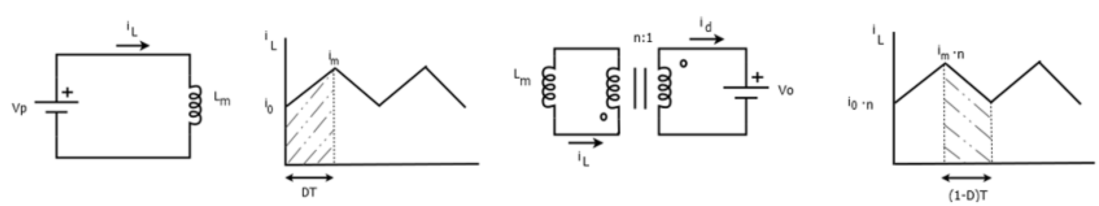


Fig.3. Power system scheme

Battery- Once the motors are chosen, the battery is selected attending to the current demanded by the motors and the autonomy hours required. The race mean duration is around twenty seconds. If there is ten races in a day, the required autonomy is less than an hour.

PV panel- A 40W PV panel is chosen in order to provide energy to the DC link and rise the autonomy hours of the robot. It is selected according to the power and its dimensions. The selected PV panel is uncommon because its length is higher than its width. This circumstance makes the aerodynamic of the robot better. The DC link Voltage is fixed to 12 V, in order to follow the MPP of the PV panel, an adequate DC/DC converter topology should be chosen. The open circuit PV panel voltage is higher than the DC link voltage (21.6 V), while the voltage at the MPP of the panel for low irradiances is lower than the DC link voltage. Therefore, a topology able to boost from lower PV panel voltages and, also, to reduce the output voltage from the higher PV panel voltages. The Flyback converter is able to boost from the PV panel voltage to the DC link voltage and decrease the PV panel voltage when it is necessary following an MPPT algorithm.

Flyback converter- The basic Flyback topology can be seen in the Figure 4. The **Flyback converter** has the same steady state behaviour than **Buck-Boost** converter. Fixing the **transformer ratio** (n) by 1 the converter boost the output voltage for **duty cycles** (D) greater than 0.5 and decrease the output voltage for duty cycles lower than 0.5. The behaviour of transformer-isolated converters can be adequately understood by modelling the physical transformer with a simple equivalent circuit for each commutation state of the MOSFET. As can be seen in the Figure 5, when the MOSFET is switched on, the current is not able to pass thought the **diode 1** (D1), therefore it flows through the **transformer's magnetizing inductance** (Lm). When the MOSFET is switched off, the current stored in the Lm flows through the **diode 1** (D1) and feeds the load.



a) b)

Fig.5. a) Switch ON interval b) Switch OFF interval

Input and output power must be the same in a lossless hypothesis. Taking that into account the expression (5) is obtained.

$$\frac{V_o}{V_{in}} = \frac{N2}{N1} \cdot \frac{D}{1-D} \qquad (3)$$

As can be seen in (5) taking N2/N1 as 1 the relation between the output voltage and the input voltage is the same as in the **Buck-Boost** converter. The advantage of the Flyback converter is the isolation, which is needed for PV generation due to safety issues when it is connected to the grid through the external charger.

***MPPT*-** There are many Maximum Power Point Tracking algorithms and each one has its advantages and disadvantages [2]. The Maximum Power Point Tracking algorithm selected was the **Incremental Conductance** algorithm. This algorithm has a better behaviour against changes of the irradiance than other algorithm and the tracking efficiency is greater. Furthermore, it can be implemented in close loop. In close loop it works properly when changing the irradiance level. Due to the fact that the robot will be moving around, the behaviour against changes of the irradiance become important, and a close loop control is appropriate.

The algorithm is based on the behaviour of the **slope** in the **PV array power curve** from a PV panel. As can be seen in the Figure 6, the slope of the **PV array power curve** is zero at the MPP and shows opposite signs before and after the MPP.

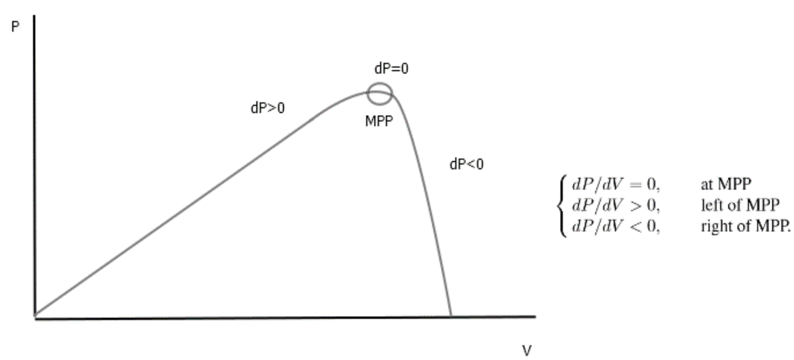


Fig.6. PV array power curve.

The complete algorithm for the **open loop** implementation is shown in the Figure 7 [2]. The value of the **slope** in the **PV array power curve** is observed replacing the power by its current-voltage dependent equivalent. Furthermore, the possible zero value of the voltage or the voltage increment must be taking in account in the calculation of the variables.

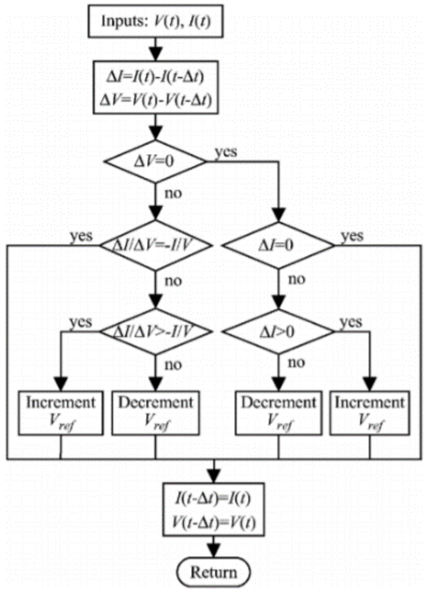


Fig.7. Open loop incremental conductance algorithm [2]

For the **close loop** implementation the error signal is define as (6). For the control, a **Proportional-Integral** controller is enough. Defining the error signal as (6), the integral controller will make the error zero. Therefore, the **PV array slope** will be also zero since the error is actually the slope value, arriving to the MPP.

$$e = \frac{I}{V} + \frac{\Delta I}{\Delta V} \qquad (6)$$

The **close loop** implementation avoids voltage ripple around the MPP.

In the next project phases the **external charger**, the **Dual Active Bridge** and the **motor driver** will be designed.

C. CONTROL SYSTEM

The **control system** is composed by two subsystems showed in the Figure 8. The first one is **the line tracking system** which correspond with the implementation of a traditional line tracker robot for the "***Liga Nacional de Robótica Competición"*** competition [3]. The second one is the **speed follower system** which is composed by several sensors which send information about the relative position of the athlete and the robot.

The speed follower system works with two limit position referents. The robot start running with its nominal speed, which can be adjusted taking into account the medium speed reached by the athlete before the competition.

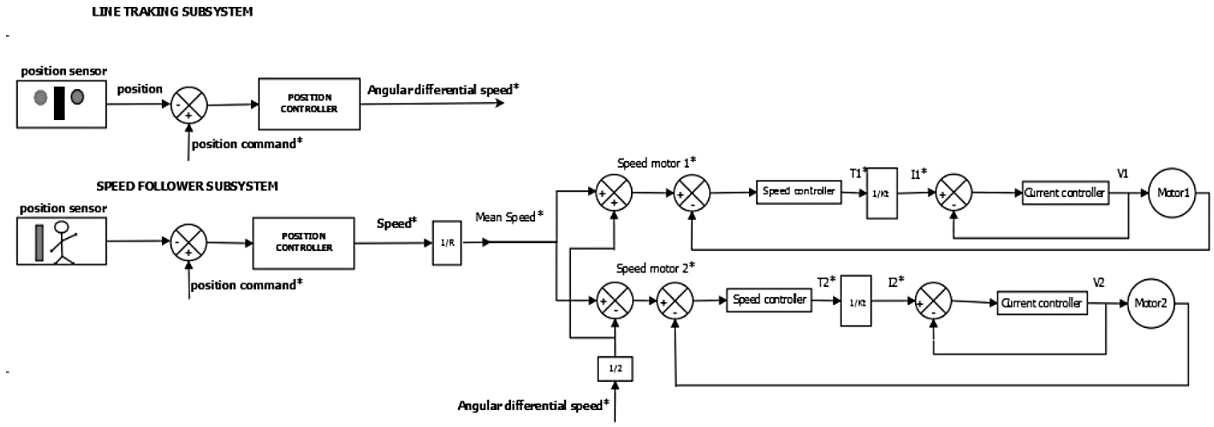


Fig.8. Control system scheme.

If the athlete overcome the **line 1** (Figure 9) the speed of the robot is higher than the speed of the competitor and the reference speed of de robot is decreased. If the athlete overcome the **line 2**, it means the robot is not being fast enough, therefore the reference speed is increased. The athlete must not realise about the speed changes of the robot, the control must be fast enough to ensure it. The complete control will be designed in the follow project phases.

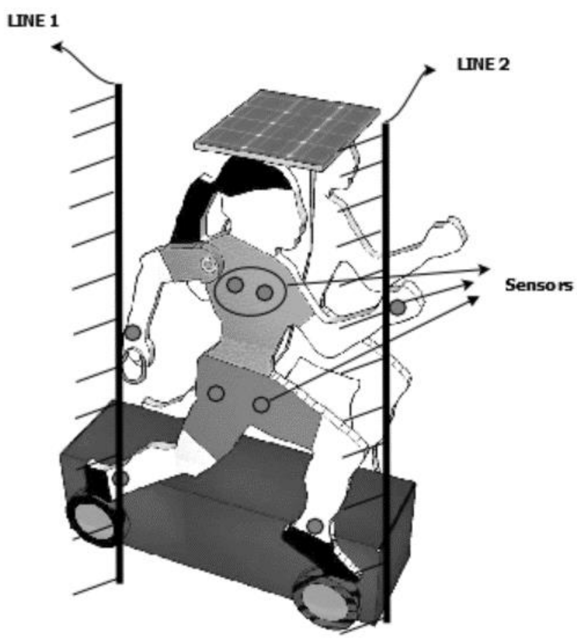


Fig.9. Speed follower subsystem operation example.

IV. CONCLUSIONS

Despite some parts of the project are not designed yet, the idea showed in this paper could change the competitive experience of the many blind people around the world. The necessity of dispense the assistant in the blind persons competitions is cover by the automatic assistant, which eliminates the problems of finding a person who has the same physical characteristics than the competitor. Furthermore it allow the athletes to compete by themselves which is an important step for the inclusion of the disabled. Finally it finishes with the illegal helps polemic which surround the competition nowadays. In addition, the robot is fed from a renewable energy source what makes the design more eco-friendly.

REFERENCES

[1] J. R. Sant, METODOLOGÍA Y TÉCNICAS DE ATLETISMO. Editorial Paidotribo, 2005.

[2] T. Esram y P. L. Chapman, «Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques», IEEE Transactions on Energy Conversion, vol. 22, n.º 2, pp. 439-449, jun. 2007.

[3] Villarmarzo Arruñada, Noelia, Alonso García, Alejandro, Molina García, Pablo y Gómez Girón, Samuel, «National Competition Robotics League».