# Trajectory Correction for Visually Impaired Athletes on 100 m Paralympic Races

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**Abstract.** The paper reports an experimental study that was carried out in Manaus (Amazonas, Brazil) with the participation of eight visually impaired athletes on 100 m sprint Paralympic races. A trajectory correction system was used, based on an accelerometer and a gyroscope for motion detection, an algorithm to track the athlete's trajectories and a haptic actuator for the interaction with the athletes. The experimental results show the relevance in the use of this type of systems in Paralympic 100 m races for visually impaired athletes, mainly with the purpose of increasing their autonomy by mimicking their guides.

**Keywords:** Visually impaired athletes · Paralympic races · Trajectory correction

## 1 Introduction

The association between sports activities and the independence of people with disabilities [1–3] existed since the 19th century due to the influence of the Stoke Mandeville Hospital in England, which introduced sports activities as part of their patients' rehabilitation programs [3]. The importance of physical activity [4], being it formal or informal, for people with some type of disabilities, including visual impairments, is patent in development of the Paralympic movement, which seeks to show the potential of the impaired athletes and, simultaneously, aims to serve as a catalyst for the rights and equal opportunities of people with disabilities by minimising barriers, including environmental barriers [2].


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The study reported by this article aimed to evaluate a trajectory correction system to help visually impaired athletes in Paralympic races. The system makes use of a haptic actuator (i.e., a wearable vibrotactile device) to provide visually impaired athletes with feedback for trajectory correction on 100 m Paralympic races. An experimental setup involving eight visually impaired athletes in training activities was conducted to evaluate the adequacy of the proposed system.

In the following sections, this article introduces the research problem, the methods that were used, the experimental evaluation, and a discussion and conclusion of the results.

## 2 Problem and Foundations

According to [5], it was estimated that in 2015 there were 253 million individuals with visual impairment worldwide. About 217 million individuals had moderate to severe visual impairment and 36 million were blind [5].

In the absence of any sensory modality, a person develops other sensory capacities or abilities, which means that in the absence of vision, touch is an excellent mechanism of sensory substitution, as observed in the use of communication methods such as Braille or Tadoma. Furthermore, touch can also be an important sensory mechanism for people without visual impairments as pointed by [6], which makes an analysis about optical sensory substitution from the perspective of neurosciences and sensory prostheses. In this respect, the author lists the characteristics that should be of great relevance to the design and implementation of tactile interfaces, striving for human sensory physiological adequacy and the plasticity of perception, in order to evidence the fluidity regarding sense-motor skills [6].

Moreover, another study [7] refers alternatives to visual mechanisms for the implementation of knowledge-based authentication systems. The authors suggest establishing a balance between security and memorization by allowing the touch when authenticating in systems related to banking or electronic points, among others [7]. In addition, the authors concluded that tactile authentication systems present several advantages when compared to visual authentication systems.

The work of [8] makes a good representation of the importance of tactile stimulation, as the authors state that the use of tactile stimuli by blind people, based on a linguistic equivalence between the graphic interfaces of electronic sites and interactive tactile interfaces, might lead to the universalization of online applications. An important contribution for this understanding is presented in [9], where the authors report a comparison of a methodological procedure based on the identification of targets and objects between visually and hearing impaired individuals and individuals without disabilities.

Still referring to the tactile interfaces, the authors of [10] and [11] developed a pattern recognition device with tactile stimulation through the use of oriented pins, which, when in contact with the skin of visually impaired individuals, allow the identification of shapes. This practice suggests sensory replacement of vision by touch. The authors of [12] refer to the use of mobile technologies such as mobile handsets or wrist devices that use tactile feedback to express some information without generating visual burden to the user. The study [12] obtained significant results regarding recognition by users of vibrating patterns up to 200 Hz when used in basic orientations such as "turning on" or "turning off", "walking fast" or "walking slowly", and "left" or "right". Another important consideration is the conclusion of the authors that auditory stimuli tend to overlap the tactile stimuli for individuals with or without visual impairment [12].

In this context, it is worth highlighting the works related to this theme, which use touch as a communication mechanism in a linguistic code perspective (e.g., [6–16]).

The technological solutions have the potential to support Paralympic athletes so that they can safely maximize their performances [17]. Some studies have sought to present alternatives for visually impaired athletes, such as the study reported in [18] that uses Goby, which is an auxiliary mechanism to provide audio feedback to swimmers (e.g., when the athlete is swimming outside the lane or is approaching the wall of the swimming pool). Moreover, the scientific literature presents studies that make use of controlled robots or drones to provide feedback to the athletes [19–23], voice assistants as an instrument to assist performance [24], portable personal navigation device that provided the current position and possible directions [25], or assistive technologies supported on location-based services [26].

## 3 Experimental Setup

### 3.1 Trajectory Correction System

In [27] is introduced a prototype for a correction system aiming sensory replacement for visually impaired athletes. The system was designed to provide more independence and autonomy for these athletes in Paralympic 100 m races and contains a motion detector based on an accelerometer and a gyroscope, an algorithm to track the athlete's trajectories and a haptic actuator. In summary this system is composed by:

- Central Control Station: a device that process information about angular variation provided from MPU-6050 chip. It is a motion detection device with three-axes gyroscope, three-axes accelerometer and a digital motion processor. By using this device, it is possible to track fast or slow movements. Based on it, control signals are used by a haptic actuator aiming to correct the athlete's trajectory.
- Tracking Algorithm: an algorithm based on a tracking topology composed by coordinating nodes and anchor nodes of a wireless sensor network aiming to locate the athletes and to track their trajectories employing triangulation techniques [28].
- Haptic Actuator: a pair of vibe board is positioned each one on the left and right arms of the athletes. Through vibration signals, the athletes realize what decisions must take to keep their trajectories within the limits of the lanes.

By the use of angular variation as suggested in [29], the motion detector provides information about the athletes' sense of orientation when performing 100 m races.

Based on the angular values measured by the MPU–6050 module combined with an actuation system, the following control actions are provided:

- Angular variation on the left: from the analysis of the scale with resolution of $\pm 2000°/s$ and $\pm 2$ g, indicative of a corrective action to turn right.

- Angular variation on the right: from the analysis of the scale with resolution of ±2000°/s and ±2 g, indicative of a corrective action to turn left.
- Without significant angular variation, from the analysis of the scale 2000/s, there is no indication of a corrective action.

Regarding the use of the MPU-6050 module, a confidence interval was defined including steering angles along the axis of rotation as show in Fig. 1.

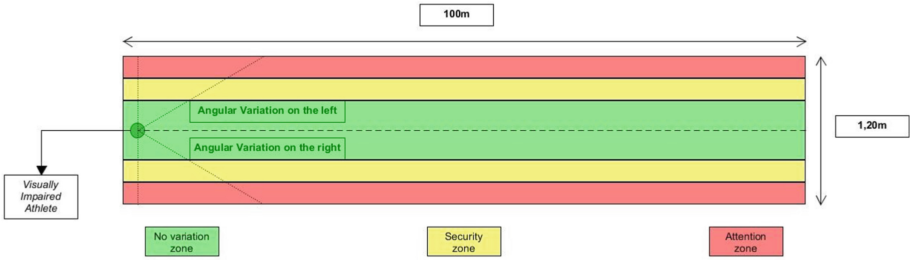


**Fig. 1.** The athlete, the pit lane and the correction.

### 3.2 Validation Tests

An experimental setup was conducted to evaluate the adequacy of the proposed trajectory correction system. For that visually impaired athletes, during their training activities, carried motion detection devices and wear a pair of haptic actuators that were positioned on their left and right arms.

The tests were carried out in the Olympic Village of Manaus (Amazonas, Brazil), with the participation of eight visually impaired athletes. The activities carried out comprised the training of 100 m race and, in terms of experimental results, the aim was to analyse the deviation of the athlete's paths on the lanes.

## 4 Results

Tests were carried out with 8 subjects, including male and female athletes, at a state competition level, aged 25 to 29 years, between the months of July and August of 2016. The athletes had between two and three years of practice.

A Research Ethics Council approved the tests once respecting the complete non-disclosure of the identification data, pursuant the General Data Protection Law of Brazil.

Figures 2, 3, 4, 5, 6, 7, 8 and 9 present the displacement profiles of the eight athletes on the outward (blue colour) and return (red colour) paths:

- Athlete 1 (Fig. 2) - on the outward path, the trajectory was corrected despite a slight deviation. In the 3rd quartile of the return path, there was a lateral displacement, and it can be observed that there was still a correction factor.

- Athlete 2 (Fig. 3) - on the outward path, behaviour of the correction system was susceptible to be improved (2nd and 3rd quartiles) but kept the athlete still within the limits of the lane. On the way back, the same behaviour was observed.
- Athlete 3 (Fig. 4) - on the outward path, the athlete's sense of linearity was evident, with the punctual performance of the correction system in the 2nd quartile. On the way back, there was a certain variation in the trajectory of the 1st quartile, with punctual and effective action by the correction system.
- Athlete 4 (Fig. 5) - on the outward path, there was a slight corrective action in the 2nd quartile and significant delay in correction in the 3rd quartile. On the return path, there was a slight deviation between the 2nd and 3rd quartiles, with a slight contribution of the correction system.
- Athlete 5 (Fig. 6) - on the outward path, the athlete's displacement was almost uniform with slight susceptibility in the 3rd quartile. On the return path, there was almost uniformity in the 1st and 2nd quartiles with significant angle variance between the 3rd and 4th quartiles and a corrective action starting almost at the end of the path.
- Athlete 6 (Fig. 7) - on the outward path, there was a slight correction in the 2nd quartile and the athlete almost meet the lateral limit of the lane in the 3rd quartile. On the return path, uniformity in movement was noted, with a positioning on the lateral limit of the lane throughout the path.
- Athlete 7 (Fig. 8) – it was observed a non-uniformity in the outward path with a corrective action between the 2nd and 3rd quartiles, as well as between the 3rd and 4th quartiles. On the way back, the displacement profile was not uniform with a corrective action in the 2nd and 4th quartiles.
- Athlete 8 (Fig. 9) - on the outward path, a corrective action was taken in the 2nd and 4th quartiles. The same was observed on the way back.

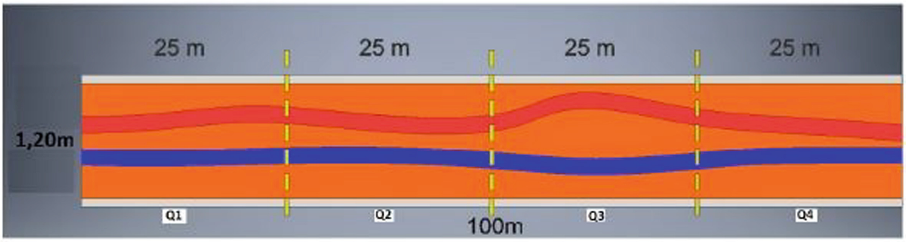


**Fig. 2.** Athlete 1 performance.

## 5 Discussion and Conclusion

Regarding the performance of trajectory correction system, despite the small sample size, it was found that the use of this type of systems on 100 m Paralympic races is relevant for visually impaired athletes, mainly with the purpose of increasing their independence by mimicking their guides.

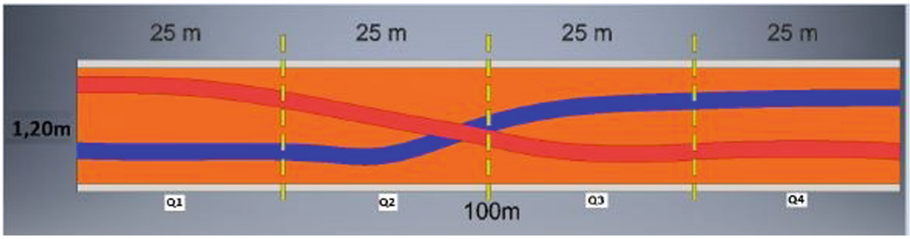


**Fig. 3.** Athlete 2 performance.

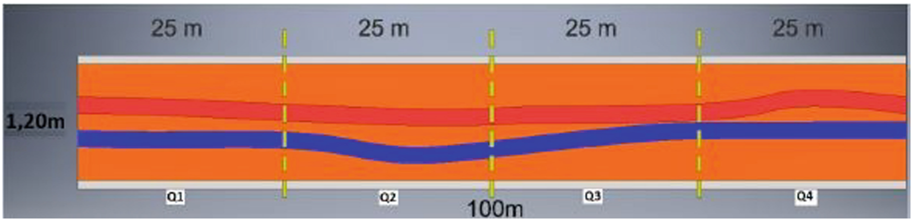


**Fig. 4.** Athlete 3 performance.

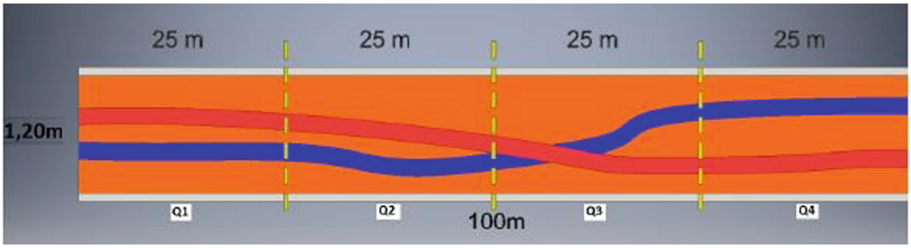


**Fig. 5.** Athlete 4 performance.

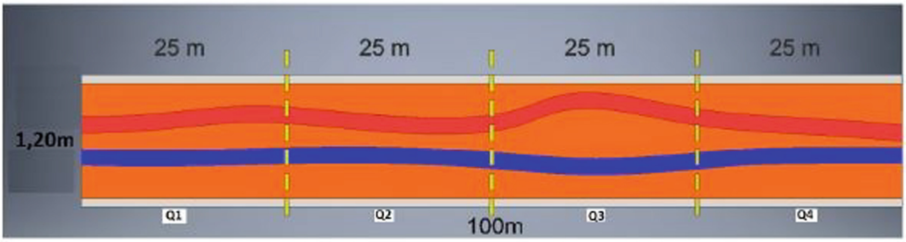


**Fig. 6.** Athlete 5 performance.

Although there was no critical failure in the measurement of angular variation in relation to the athlete's living axis, variations in the displacement profiles were observed. When analysing the displacement profiles of at least five athletes (i.e., athletes 2, 4, 5, 7 and 8) it is possible to observe significant needs for corrections. For instance, in the

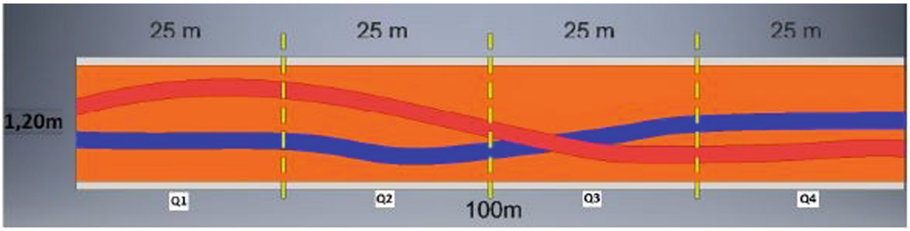


**Fig. 7.** Athlete 6 performance.

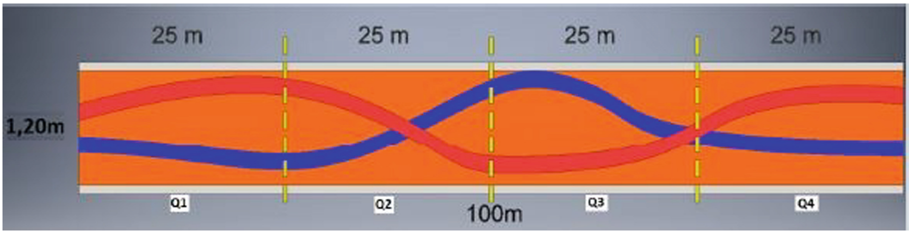


**Fig. 8.** Athlete 7 performance.

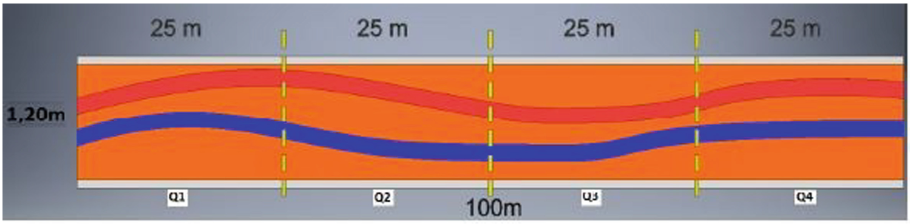


**Fig. 9.** Athlete 8 performance.

trajectory of athlete 7 (Fig. 8), it is possible to observe an error pattern in the outward and return paths, with sudden changes in the 2nd and 3rd quartiles. These limitations might compromise the athlete's performance during official races.

In turn, the inexperience of athletes in using the system might justify some deviations, which means that further tests need to be performed to evaluate the system by visually impaired athletes with experience in using the system.

As a conclusion, it is propitious to affirm that this study contributes to transform any physical limitation of an individual into an instrument of innovation since the trajectory correction system that was evaluated might promote the independence of the visually impaired athletes regarding the execution of their training activity.

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