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THE CASE FOR THE WIRELESS AD HOC SYSTEM FOR POSITIONING AND ITS USE IN SPORTS

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Abstract: Wireless tracking provides opportunities in several fields, among which elite athlete training. CSIRO has been able to develop a new system, which overcomes certain limitations other localization systems are faced with. We all know and we are habituated to use Global Positioning System (GPS) that has the advantage of long period of use from releasing it into the market until now, that means the problems, normal to appear at the beginning were solved, the hardware for this method was developed in many generations, now almost everyone using it in one way or another. As a logic consequence the military applications developed much faster with spectacular results. We are using now the Global Positioning System on airplanes in order to back up the old systems and to avoid catastrophic accidents, to track the routes and recently connecting the black box of the plane with a real time transmitter and a control unit situated on the ground, that allows all information available, to check them in order to ensure the safety of the flight is ok and to transmit to the air crew solutions on various problems. The system that we propose is just at the beginning but we hope that it's much better precision will be a fundamental advantage.
Keywords: wireless, sports, GPS, WASP, tracking, collects, soccer

1. INTRODUCTION

With the development of wireless localization, be it through infrastructures such as cellular, sensor network, or new ones developed with a certain field in mind, the use of localization technologies in sports has undoubtedly become apparent.

In a 2012 IEEE Computer Society article, Hedley and Zhang took a closer look at the accuracy of such systems and proposed the use of the wireless ad hoc system for positioning(WASP) for increased accuracy [1, 2]. This study touches on fields inside of computing science, as well as outside of it. The fields of computing science touched on are physical structures, reliability, testing, and fault-tolerance, as well as wireless communication. Outside of computing science, we are faced with issues from the fields of sports and psychology, posing questions such as: How will overcoming tracking limitations help coaches improve the players performance? How will elite athletes gain a competitive edge? And will team interaction and performance be affected by the existence of such systems?

In this essay, we are going to take a further look at the issues regarding wireless localization in sports and provide insight into WASP's performance monitoring.

1.1. Wireless localization systems

The development of the global positioning system (GPS) has led to several other localization systems receiving more interest, especially in area where GPS lacks to fulfill its duty. For example, there are several area where GPS is unavailable, not to mention the fact that GPS does not work indoors. What is more, it is limited, the accuracy often being worse than a meter thus inadequate for sports tracking [1,5]. The issue with elite sports tracking comes from problems such as lack of high accuracy, the necessity of high update rates due to rapid movement, and the need to track several athletes at the same time. Therefore, effective tracking systems have to face the issues of high accuracy and high update rates.

What factors in high speed accurate localization is ranging. „Ranging is the process of determining distance. Localization systems estimate range by measuring received signal strength (RSS) or propagation time. Ranging with RSS is sensitive to channel variation and has low accuracy. Thus, propagation-time-based ranging is most suitable for sports."

In order to improve ranging accuracy we need to take a look at the timing accuracy, which is dependent on the multipath signal. Improved results can be achieved with the use of a larger signal bandwidth. On the other side, this can lead to a reduced signal in the case of a multipath channel.

Another method to improve localization systems is by enhancing the signal-to-noise ratio (SNR). The analysis of this element is typically done through cross-correlation. However, Hedley and Zhang bring up auto-correlation in order to collect multipath energy." Ideally, the training sequence has a constant magnitude across the signal bandwidth in the frequency domain and has the ideal circulant autocorrelation property—that is, the autocorrelation has a single peak at zero lag and is zero elsewhere. To detect the first multipath component, the computation can normalize the autocorrelation to the power of the difference between the received signal and its delayed version. This approach outperforms conventional cross-correlation based approaches in the sense that it achieves a higher SNR in dense multipath channels."

1.2. Wireless ad hoc system for positioning (WASP) overview

The Commonwealth Scientific and Industrial Research Organization (CSIRO) is the Australian government research organization, which has developed WASP. This localization platform has been developed to work in difficult environments in which GPS and WiFi do not work. For instance, underground, inside building or even in disaster zones. WASP's main application areas include elite athlete training, mining and emergency management/disaster zones [3, 4, 6].

WASP uses low cost, portable radio hardware in order to achieve high accuracy and high update rates in tracking. WASP operates in the 5.8 GHz industrial, scientific, and medical (ISM) purpose band, focusing on improving accuracy by using the entire 125 MHz bandwidth.

The WASP network features nodes. Certain amounts of these are called anchor nodes and are placed on known fixed locations, whereas the others are called mobile nodes. Mobile nodes, as the name suggests, are attached to the tracked object(s). In elite sports tracking, the anchor nodes are generally placed surrounding the area to be tracked, using the measured time of arrival (TOA) to calculate the range between the anchor nodes and the mobile nodes.

The anchor nodes are wirelessly connected, thus making WASP a system unlike any other available on the market. „Thus the system can be rapidly deployed without disturbing existing infrastructure in the venue and enabling a single system to be used in multiple venues. The system also provides a data channel operating up to 8 Mbit/sec that can transmit a range of sensor data" [9].

„There are several processing stages used by the system. Each node transmits a periodic beacon, and all nodes receiving the beacon use a super-resolution algorithm to determine the TOA with high accuracy (better than one nanosecond in indoor sporting environments). Through the exchange of transmit and receive time between nodes the range between nodes is determined, correcting for time and frequency offsets, node motion and variable signal propagation delay in the electronics. The location of the mobile nodes is computed using multi-lateration and a tracking filter reduces noise and provides velocity estimates. The system provides a tradeoff between the maximum number of tags simultaneously tracked and the update rate of each tag. The maximum update rate is 125 Hz.". With the use of this process, WASP can achieve high accuracy (under one nanosecond), which is ideal for sports training.

2. WASP SYSTEM PERFORMANCE

The Australian Institute of Sport (AIS) teamed up with CSIRO in 2007 for the trial and further development of WASP. There have been trials in football, rugby, basketball, track cycling, and several other sports.

The first set of tests we are going to be referring to is a cycling one, having taken place in a steel building, thus making it impossible for other tracking systems such as GPS to work in these conditions.

In the first trial, the nodes were placed on tripods and surveyed in order to determine their locations. Upon comparing these results to the WASP generated results, the median location error is 0.13 meters, the results showing high accuracy for over 90% of the given cases.

The second trial was focused on determine the accuracy in a dynamic environment. For this trial, two nodes were attached to a bike and computed the distance using WASP. After comparing the resulted distance with the given physical distance, we have concluded that the error was 0.09 meters on average.

Therefore, it shows that WASP is a high accuracy system, able to track players relative and absolute locations with very little error.
The second set of test we will be looking at serves to help coaches learn more about decision making in correlation to experience in dynamic games, in this case netball. The lack of prior research in this area was mainly due to the difficulties of tracking multiple athletes in real time but WASP made that possible. The aim of the task was for the attacking team (n=2) to achieve the highest number of passes in 20 s inside a 10 m diameter circle while playing against one defender from the same group there by creating a two versus one (2v1) situation (i.e., piggy in the middle), figure 1. Each group completed 30 trials with outcome scores and athlete movement coordinates collated for post processing analysis. [2, 3, 7, 8]. The results of this test have been displayed in the picture below. What we can learn from this set of data is that coaches and scientist can showcase the skill and coordination among the athletes using the output of WASP. Performance wise, experts can tell the experience and skill level of a player based on the randomness of the ball's trajectory. What is more, this can help implement new strategies and deal with players' shortcoming.

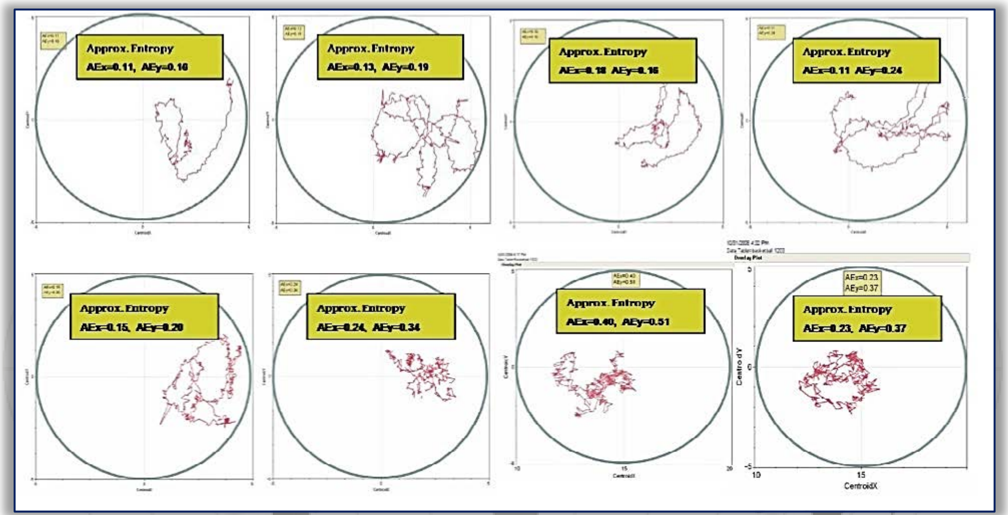

Figure 1: Tracked centroid pf three players

2.1. Mathematical test results

After several tests, WASP could be evaluated based on ranging performance, localization performance, and comparison to existing systems.
Under ideal conditions, WASP ranging resulted in the following formula (1):

$$\sigma_r^2 \geq \frac{1}{8\pi^2 \gamma BW^2} \quad (1)$$

where γ represents the signal to noise ration (SNR) and BW the bandwidth.
Taking the ranging tests outside of ideal conditions and applying them to an indoor soccer game concluded to 85% ranging errors being under 15cm.
WASP's localization performance was tested in both static and dynamic scenarios. Upon calculating the separation errors, aka the difference between the true and the calculated distance, it resulted in under 0.5 meters for both algorithms used [10, 11].
Compared to data received from other already existing systems, WASP shows consistent highly accurate tracking. For other systems, the bandwidth drops from 500 to 40 in indoor conditions, whereas WASP maintains a constant 125MHz bandwidth. Performance wise, it has been proved to show half as many ranging errors compared to other systems, with the highest error being at 48 cm, in sheet rock/aluminum stud, non-line of sight tracking conditions, performance comparison with other systems, μ_r mean ranging error, μ_p mean location error and P_e probability ranging error, table 1.

Table 1. Performance comparison with other systems

Ref.	Environment	BW(MHz)		Performance	
		Ref.	WASP	Ref.	WASP
[9]	Steel and LoS	500	125	μ_r= 66 cm	μ_r = 38 cm
[9]	Sheet rock/aluminum stud, NLoS	500	125	μ_r = 91 cm	μ_r = 48 cm
[4]$^{\alpha}$	Several buildings, NLoS	100	125	60%, P_e< 3 m	65%, P_e< 0.5 m
[1]$^{\beta}$	Wood building, NLoS	150	125	μ_ρ = 0.49 m	0.49 m
[25]	Office building, NLoS	40	125	RMSE = 1.23 m	RMSE = 0.61 m

2.2. WASP and elite sports training

Coaches and athlete themselves have struggled with real-time performance tracking for a long time due to lack of accuracy or update rates being too low, or simply because popular systems such as GPS are not available indoors and in certain secluded areas.

With the development of WASP through CSIRO and AIS, we now have a system which can operate even in difficult conditions, surveys showing little to no error both in indoor and outdoor areas, as well as in dynamic conditions such as ball games.

AIS as well as Catapult Sports, a world leader in athlete tracking devices, is still undergoing research featuring WASP, having integrated the technology into their systems, making it available worldwide therefore making a significant impact on the current state of elite training. This system enables tracking in sports where it was impossible before due to the fact that they are exclusively played indoors, such as hockey. Thus, it opens new doors to elite performances and real-time insight to be gained.

2.3. Ethical and societal issues

One major ethical issue localization systems face in the field of sports is regarding privacy. What is more, given the data from such systems and what coaches can draw out from it might influence the coaches to act differently from usual. For instance, players could get fired or have their pay cut based on data analysis which would not be possible without WASP.

This kind of issue could potentially change the economics of sports completely, player acquisitions, buy-outs, or firing becoming completely reliant on performance data, thus treating players as a „product". That concept by itself can raise many controversial opinions, having been a widely discussed ethical issue.

3. CONCLUSION

WASP was designed to provide high accuracy tracking while making use of a fast setup and low cost but high update rate hardware. Upon conducting trials in several sports, it has proved to be useful to expand the ways in which coaches can work to give a team or player a competitive edge.

In our opinion, despite still undergoing trials, WASP can be a useful tool not just in sports training but also in difficult situations, such as indoor or underground localization. WASP has benefits that surpass other currently available localization systems, and has the potential to change the way we look at sports training.

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