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Application of remote velocity measurement and location technology for sports training

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ABSTRACT: With the rapid development of computer technology, GPS can not only determine the real-time location of a motion carrier, but also determine its instantaneous velocity. However, the application of GPS for velocity measurement is not as valued or as popular as it is for location determination. Velocity measurement and location technology have very wide applications in sports. For example, it could have been an important application for *throwing* sports. The GPS velocity measurement and location technology provide a new technical way and practical method for the measurement of velocity and location in sporting events; GPS technology is widely used in sports training and competitive refereed events. Used in throwing sports teaching or training, a GPS positioning chip can be fixed onto throwing equipment. Students or athletes could make timely adjustments to their throwing motion, speed and direction in order to improve their effectiveness.

INTRODUCTION

In recent years, with the improving standard of living and the rapid development of computer hardware and software, the traditional sports training methods appear relatively backward. For example, consider throwing events. Traditional training methods just rely on the coach's experience to develop a training plan.

Athletes depend on experience to adjust the angle of the throwing object, rudder angle and strength of grasp by which to improve training. On the other hand, a coach evaluation of training depends upon personal observation, with the help of video playback to evaluate the training. This is very subjective and not scientific [1].

The GPS dynamic measurements include position, velocity and orientation; GPS can be used to determine the velocity vector and dynamic location of an object. Research on the application of remote velocity measurement and location technology in sports training is of great significance for scientific training and improving the results of competitions.

OVERVIEW OF GPS TECHNOLOGY IN VELOCITY MEASUREMENT AND LOCATION

The GPS satellite location system is all-weather, global, continuously available and is precise and convenient to use. It quickly became the main location method, deeply affecting many aspects of human activity. Current GPS systems can be used for navigation by determining location and velocity [2].

Pseudo range and carrier phase measurements determine single point locations, while the pseudo range differential method allows static and dynamic measurements. A GPS receiver installed in a carrier can determine the dynamic location and velocity of the carrier in real-time even when it is not in uniform motion [3].

The basic principle of GPS satellite location is the ranging intersection method used in surveying and mapping. It relies on detecting three or more GPS satellites to determine location on the ground. The GPS satellite signals contain the satellite location information that GPS receivers detect. The receiver calculates the distances to the satellites and, by knowing the co-ordinates of the satellites, uses the distance intersection method to calculate the location of the receiver on Earth.

The GPS receiver on the carrier obtains the carrier's velocity. The installed GPS receiver can determine the location and velocity in real-time even for non-uniform motion. The GPS receiver uses three measures: pseudo range, carrier phase and Doppler frequency shift. The pseudo range and carrier phase are used in GPS location determination, while the Doppler frequency shift is used for the velocity measurement.

THE PRINCIPLE FOR VELOCITY MEASUREMENT AND LOCATION BY GPS

The velocity measurement and location use the GPS satellite constellation, ground monitoring and control system, and the GPS receiver, as shown in Figure 1.

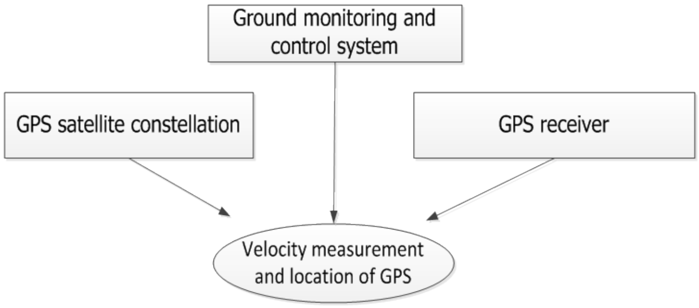

Figure 1: Velocity measurement and location by GPS.

GPS Satellite Constellation

The GPS satellite constellation consists of 21 working and three spare satellites. The 24 satellites are uniformly distributed in six orbital planes at an orbital inclination of 55 degrees. The satellites in each plane are 60 degrees apart. The number of satellites visible above the horizon range from four to 11 depending upon time and place. To use GPS to determine a location in three dimensions requires four GPS satellites, called a positioning constellation.

Ground Monitoring and Control System

The GPS satellite location is known based upon the orbital parameters. Each GPS satellite broadcast ephemeris is provided by the ground monitoring and control system. The ground equipment monitoring and control monitors the health of the satellite. Another important role is to synchronise time on the satellites, i.e. the GPS time. This would require monitoring the time for each satellite but the satellite clock is not adequate. However, the ground station injects a correcting signal to the satellite. The GPS satellite ground monitoring and control system includes a master station and three injection station.

GPS Receiver

The GPS receiver captures the selected satellite signals, to measure the propagation times, and so calculates the three-dimensional location and velocity of the receiver. With static positioning, the GPS receiver is fixed, and accurately measures the GPS signal propagation times, using the known positions of GPS satellites in orbit; hence, solving the three-dimensional co-ordinates of the receiver. With dynamic positioning, a moving object is measured by the GPS receiver. The moving object carrying the GPS receiver is called the *carrier*, e.g. a ship, aircraft, vehicle, thrown javelin. The GPS receiver on the carrier measures in real-time the state parameters of the carrier.

The receiver hardware and software, as well as the GPS data post-processing software package, form the complete GPS user equipment. The structure of the GPS receiver is divided into an antenna unit and a receiver unit. For geodesic type receivers, units are generally divided into two independent parts: an antenna unit connected by cables to the receiving unit.

ANALYSIS OF FLYING TYPE FOR A SPORTS THROWING PROJECT

The trajectories of thrown objects can be divided into four types: parabolic, prone type linear, after the gun type track and eruption track type [4] (see Figure 2).

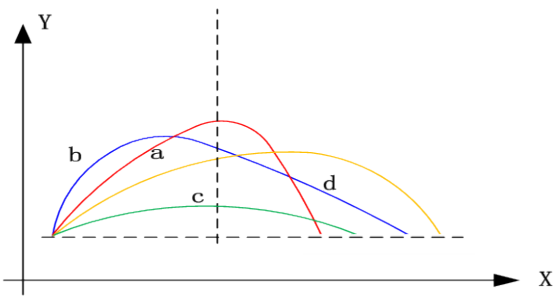

Figure 2: Flying type for sports throwing project.

Parabolic Trajectory

For a 45 degree launch angle, for say a javelin, the rising curve distance and falling curve distance are equal, and the parabolic curve is symmetrical. This angle produces the longest distance for the javelin.

Prone Type Linear Trajectory

The javelin moves in a very short period of time to the highest point and appears to glide for a relatively long time from the highest point. The javelin landing angle is relatively small.

After Gun Type Trajectory

The javelin is thrown away from the hand relatively parallel to the ground, with no obvious rise or fall. It is often difficult to determine when the glide appears. The javelin landing point is the minimum; sometimes a referee will find it difficult to determine javelin placement. The whole flight process is so fast, it is called the track speed type.

Eruption Track Type

The javelin moves after throwing with a large horizontal velocity. The impulse is smaller and the rise time is longer, and the vertical velocity is small. The glide is short, with most javelins landing at an angle of around 35 degrees.

Throwing Trajectories

The javelin is thrown along the shoot angle, where it will eventually glide relying on air lift. From the highest point along the arc, the process is similar to a free falling body and has very little to do with the early speed lower down.

APPLICATION OF REMOTE VELOCITY AND LOCATION MEASUREMENT IN THROWING

Based on the high accuracy of GPS velocity and single point positioning error correction, a GPS single point positioning and dynamic velocity measuring method is proposed in this article. The method has been verified to greatly improve the accuracy of GPS dynamic positioning [5]. The basic idea of this method is shown in Figure 3.

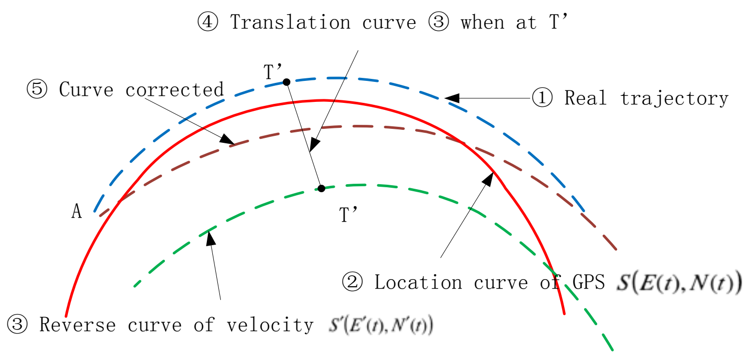

Figure 3: Remote velocity and location measurement using GPS.

Within the time T_0-T_n, the real trajectory for the curve of the moving object is given by Equation 1, and the GPS single point positioning measurement path curve is given by Equation 2. Each point co-ordinate is $S(E(t),N(t))$, where $E(t),N(t)$ are respectively the research object's longitude and latitude. A velocity inversion of the trajectory curve is given by Equation 3. Point co-ordinates are $S(E'(t),N'(t))$. Using $S(E(t),N(t))$ and $S'(E'(t),N'(t))$, the error $\Delta S(\Delta E(t),\Delta N(t))$ can be calculated. Taking the average of $\Delta S(\Delta E(t),\Delta N(t))$, yields $\Delta S_p(\Delta E_p(t),\Delta N_p(t))$. This produces a good estimate of the average time error in T_0 -T_n. The difference value $\Delta S'(\Delta E(T'),\Delta N(T'))$ is the curve correction quantity, Equation 3. This leads to the final calibration curve, Equation 5. The instantaneous velocity is calculated according to the Formulae 6 and 7, and is calculated for each point of latitude and longitude.

$$\Delta\theta_j = \theta_{j+1} - \theta_j \tag{1}$$

$$|\Delta V_j| = |V_{j+1}| - |V_j| \tag{2}$$

$$W = {}^{|\Delta V_j|}\!/\!_{n} \tag{3}$$

$$S_{j,1} = S_{j-1,n} \tag{4}$$

$$S_{j,i}(E) = S_{j,i-1}(E) + W \times \cos\left(\theta_j + i \times \Delta\theta_j / n\right) \times L_E \quad (5)$$

$$S_{j,i}(N) = S_{j,i-1}(N) + W \times \sin\left(\theta_j + i \times \Delta\theta_j / n\right) \times L_N \quad (6)$$

$$S_{j+1,0} = S_{j,n} \quad (7)$$

(i = {1, 2,..., n} are the interpolation points, i.e. respectively the latitude, longitude and distance).

APPLICATION OF GPS TECHNOLOGY IN TEACHING THE THROWING OF JAVELINS

Freshmen learning to throw the javelin were randomly selected from two parallel classes at Xi'an Sport College. Each class had 30 students and were statistically equivalent being taught by the same teacher using the same teaching methods. The students were divided into an experimental group and a control group. The experimental group used GPS technology and the control group did not use GPS technology. The process of throwing the javelin is divided into four movements: the run-up, cross-reference guns, throwing and the trajectory of the javelin. The teaching was divided into eight classes, i.e. four for the experimental group and four for the control group. The scoring details are shown in Table 1, where the javelin is referred to by the synonym, dart.

Table 1: Effect of the use of GPS technology in teaching dart throwing.

Class time	Teaching content	Group	Number of cases (N)	Excellent %	Good %	Barely passed %	Failed %
1-2	Learning run-up: whether or not centre of gravity of the dart is stable	Control group	30	40	27	20	7
		Experimental group	30	53	34	17	6
3-4	Technology of steps across to throwing: the angle and speed of the leading edge of the dart	Control group	30	25	43	26	4
		Experimental group	30	29	48	20	3
5-6	Throwing technique: instantaneous speed and angle of the dart	Control group	30	33	20	27	20
		Experimental group	30	41	27	25	7
7-8	Path through the air of the thrown dart	Control group	30	16	32	40	12
		Experimental group	30	23	46	26	5

In Table 1, it can be seen that, after a four-stage teaching process, most students master javelin throwing, but students from the experimental group, who used GPS distance measurement and positioning technology, achieved a higher proportion of *excellent* and *good* assessments than did the control group, who did not use GPS technology. This was due to the students in the experimental group receiving timely feedback on their strengths and weaknesses and, hence, could improve more during the classes.

Table 2: The results using variation coefficients.

Group	Coefficient of Variation CV	The probability that the difference between two groups is not significant
Control group	0.26	$P \leq 0.05$
Experimental group	0.19	

Table 2 displays the coefficient of variation of the control and experimental groups as 0.26 and 0.19, respectively, showing there are significant differences between the groups at a significance level of $p \leq 0.05$.

IMPLEMENTATION OF GPS SIGNAL ACQUISITION FOR SPORTS

In GPS receiver hardware, the antenna receives digital, medium frequency signals from the first filter in the RF module. A special chip determines the Doppler frequency shift and the local pseudo random code for related operations. The signal is decomposed into multiple signal channels for demodulation [6]. Demodulation of the navigation information allows the positioning module to calculate the location. The GPS software does most of the signal processing software, giving the software receiver flexibility and scalability, compared with a traditional receiver. For example, a new signal processing algorithm only requires modification and test of software.

The GPS software receiver and the traditional hardware and receiver are, obviously, different as is shown in Figure 4. Signal relevant parts are moved to the general processor and implemented as software. The only hardware parts needed is a variable frequency digital sampling unit, with the digital intermediate frequency signal stream transmitted to the computer, where the computer software does the capture, track demodulation and positioning calculations.

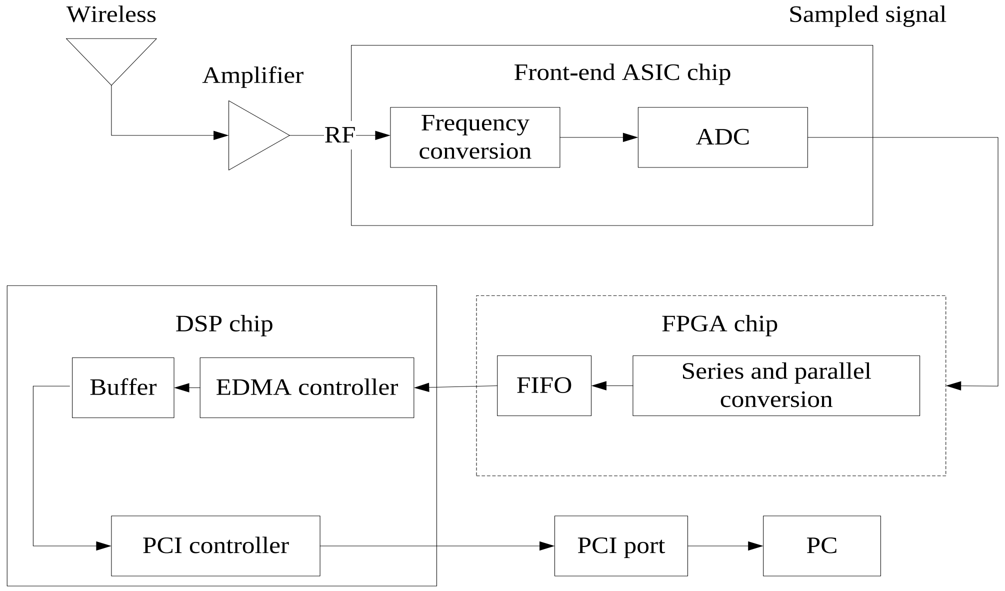

Figure 4: Implementation of GPS signal acquisition for Sports.

The hardware is divided into an antenna and low noise amplifier, frequency conversion and mining model, data acquisition card and PC. The software part of the implementation includes signal acquisition data flow control, FPGA (field programmable gate array) program, DSP (digital signal processing) program, PC driver and control interface program. The GPS software receiver is a hotspot for research in the field of satellite navigation and positioning. The constant improvement of the technology can effectively solve the positioning terminal of frequency drift and phase noise, false signals generated by mixing, amplification by harmonics and intermediation and machine noise. This is advantageous for the algorithms and software optimisation, as well as improving the positioning accuracy.

CONCLUSIONS

The GPS can be used to determine the speed and position of its carrier, and navigation is one of the main uses. But GPS can not only determine the real-time location of a moving object, but also its instantaneous velocity. The GPS location technology and the velocity measurements can find new uses in sporting events. Research shows that the method is feasible and provides a new technical and practical method that could make a great contribution to the development of physical culture and sports.

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