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ORIGINAL ARTICLE

New jump trajectory determination method using low-cost MEMS sensor fusion and augmented observations for GPS/INS integration

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Abstract Objective information on athletic maneuvers for performance evaluation has become highly desired in sports such as skiing, snowboarding, and mountain biking. Body-mounted devices, incorporating low-cost microelectromechanical, inertial navigation units, and global positioning system (GPS) receivers, to calculate sport-specific key performance variables (KPVs) and provide real-time feedback, are now commercially available. However, algorithms implemented for such purposes still lack accuracy and power efficiency. A new GPS/INS (inertial navigation system) integration algorithm is proposed to determine the trajectory of an athlete executing jumps while skiing, snowboarding, mountain biking etc. KPVs, such as jump horizontal distance, vertical height, and drop, are calculated from the trajectory. A new sensor error compensation scheme is developed using sensor fusion and linear Kalman filters (LKF). The LKF parameters are varied to address the fluctuating dynamics of the athlete during a jump. The extended Kalman filter used for GPS/INS integration has an observation vector augmented with sensor error measurements derived from sensor fusion. The performance of the proposed algorithm is evaluated through experimental field tests. For the determination of jump horizontal distance, height, and drop, the proposed algorithm has errors of 14.3 cm (5.5 %), 1.6 cm (38 %), and 6.7 cm (9.4 %), respectively. Errors in KPVs for a set of jumps were first determined with respect to the true KPVs, and then the errors for all the jumps were averaged to calculate the absolute and percentage errors. The accuracy achieved is deemed to fulfill the expectations of both recreational and professional athletes.

Keywords MEMS · GPS · INS · Jump trajectory

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Introduction

Well-executed and stylish routines consisting of complex aerial acrobatic maneuvers are highly appreciated in sports such as skiing, snowboarding, mountain biking. Unfortunately, the athletes and spectators typically have only a qualitative sense of the key performance variables (KPVs), for example, jump horizontal distance, jump height, and jump drop. During competitions, performance is also evaluated with subjective measures, referred to as 'overall impression', by a panel of judges (Harding et al. 2007a). During training, in the absence of objective measurement tools, athletes and coaches must largely rely upon subjective perceptions when evaluating performance.

Recent analysis has revealed that sport-specific KPVs strongly correlate with the subjectively judged scores in competition (Harding et al. 2007b). Therefore, judges, coaches, and athletes could be greatly assisted by any complementary tools that objectively measure the sport-specific KPVs. Although video-based assessment is widely used for training and evaluation, it is often misleading. Furthermore, video-based performance analysis is generally time-consuming and requires considerable infrastructure. In addition, it is often very difficult to acquire and analyze KPVs information through labor intensive