

SKI ORIENTATION DETERMINATION FROM GPS/IMU DERIVED TRAJECTORY

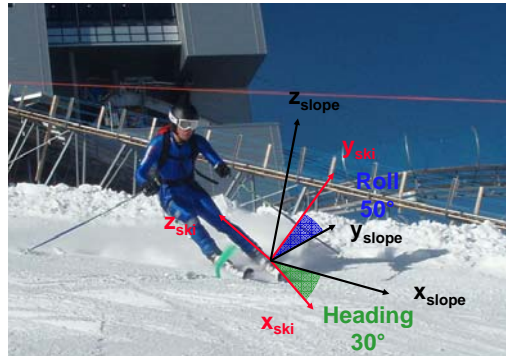
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Context

In alpine skiing, the determination of accurate orientations of a ski is the prerequisite for analyzing forces acting on the ski.

Forces need to be decomposed with respect to the terrain in order to analyze potential and kinetic energy, as well as joint loading and energy transfers during a turn.

The described method proposes a new approach which is **more accurate, faster, easier to setup and insensitive to the weather conditions.**



Experimental Setup

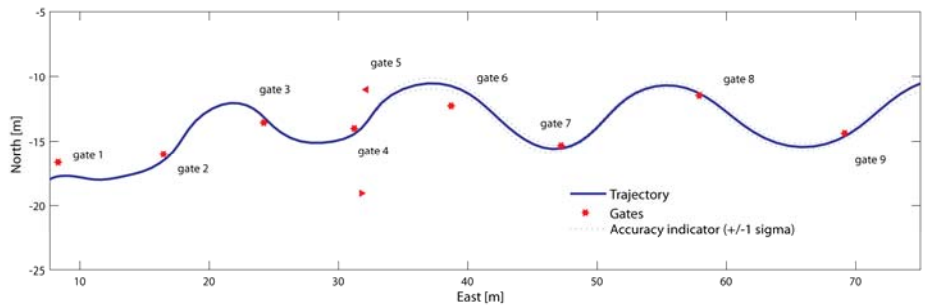
The method relies on the trajectory determination provided by the integration of **low-cost GPS (Global Positioning System)** and micro-electro-mechanical system (MEMS) **inertial measurement units (IMU)**. As the skier's environment quickly alternates between open spaces and areas that block satellite signals, the computation of GPS positions and velocities is sometimes difficult or even impossible. Therefore, MEMS-IMU sensors are integrated with GPS.

For a complete investigation, the right and the left foot need to be equipped with GPS and MEMS-IMU sensors to recover the position and orientation of both skis.

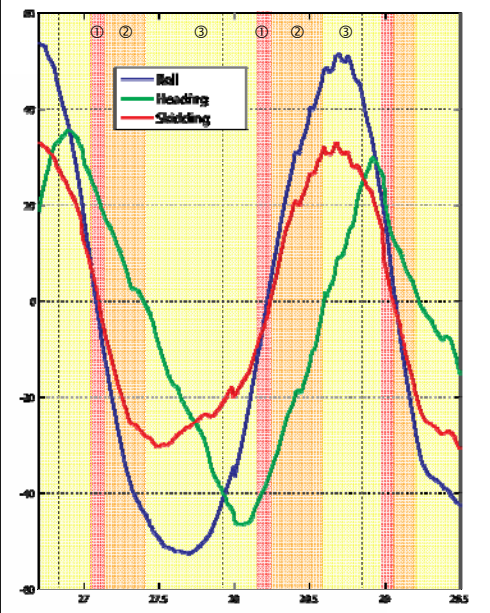
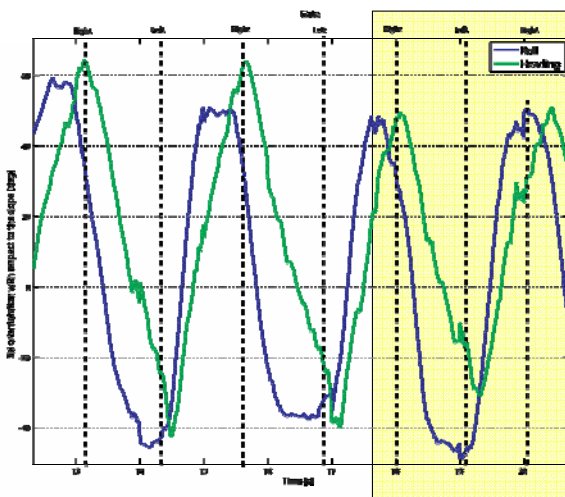
Ski Trajectory and Orientation

The GPS/MEMS-IMU integration provides **position and velocity accuracies at decimeter level**. The accuracy level is indicated by a confidence interval ("snake" around the trajectory).

The orientation of the ski is computed with respect to the local level reference frame (North, East, Up). The orientation from GPS/MEMS-IMU integration is estimated with an **accuracy of 1-2° (1σ)**.



Skiing Technique Related Analysis



Based on the slope provided by a digital terrain model and the results of the GPS/MEMS-IMU integration, the **orientation of the ski with respect to the slope** can be computed.

The local referential (x, y, z_{slope}) is defined as follows: the xy plane represents the local surface where the x -axis is given by the orientation of the maximum slope of the terrain. The heading is the angle between the direction of the maximum slope (x_{slope}) and the direction of the ski (x_{ski}). The roll describes the edging of the ski.

The zoom on the two turns allows to study the technique of the athlete:

- During the initiation of the curve (①), the ski is flat (roll = 0°).
- The first phase of the curve (②) lasts until the ski is orientation in the direction of the maximum slope (heading = 0°). During this phase, the roll angle increases gradually and reaches its maximum towards the end.



Based on the orientation of the ski and the ski's trajectory provided by the GPS measurements, the **skidding of the skis** can be analyzed. This angle is zero at the initiation (①) and increases during the first phase of the curve (②).

