Data science in top-level ski racing

Development of a model-based Key-Performance-Indicator for the Super-G

Graduate

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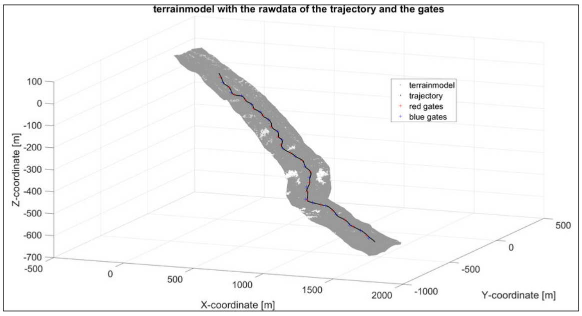
Objective: In this bachelor thesis, a model-based key performance indicator (KPI) for Swiss ski racing was developed for a more accurate analysis and optimization of training or competition runs in alpine ski racing. To assess how well a racer's run was executed on each track section, GPS data of training and competition runs (trajectories) were measured and compared to the best possible run of a virtual racer. This virtual racer is based on a dynamic mathematical model of a skier who would run the same course under optimal conditions.
The recorded raw data of the terrain model were preprocessed by HEIG-VD in Yverdon and the GPS data of the runs were recorded by Insiders.live SA in Lausanne. The GPS data of the trajectories were sampled at 10Hz. However, since in alpine ski racing hundredths of a second decide about victory or defeat, these trajectories are first smoothed with a Savitzki-Golay filter and then upsampled.

Approach: For later analysis, the trajectory is divided into segments so that each segment can be assigned to a curve and analyzed independently. In this way, the identification of those sections, where the racer has potential for improvement, can be determined more precisely.
The calculations are based on a simplified physical model in which the ski racer is assumed to be a point mass. The following forces act on the skier:
- The weight force of the ski racer (F_G), which is split into a part tangential to the trajectory (F_V) and a part perpendicular to the trajectory (F_N)
- The centrifugal force of the ski racer(s) in the turns (F_P)
- The frictional force between the ski and the slope (F_R)
- The air resistance (F_L)

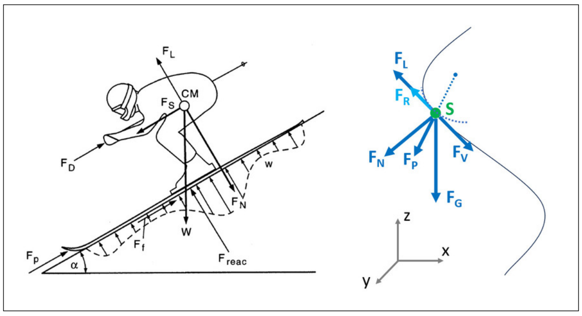
Using Newton II, an equation of motion is derived. By solving this differential equation, the maximum possible terminal velocity for each segment can be calculated.

Result: The developed tool enables the coaches of the Swiss Ski Team to identify specific sections of the course which the athletes have skied very well or poorly. In addition, the maximum possible exit speed per segment gives them an indication of how far the athletes are from the ideal ride.
By means of additional data and an extension of the friction models for different track sections (gliding, carving, steep curve, etc.), the model of the virtual skier can be further improved and detailed, so that even very inhomogeneous track sections can be better evaluated.

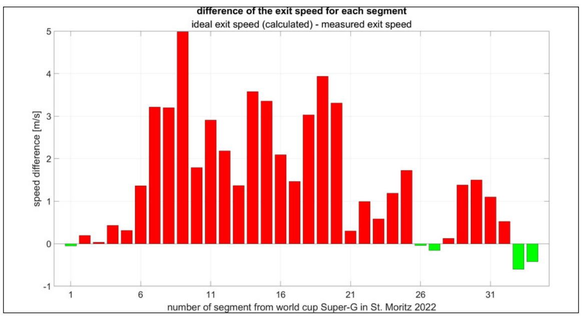
Visualization of the slope from the women world cup Super-G 2022 in St. Moritz (terrain model, trajectory and gates)
Own presentment



Model with the forces F_G, F_V, F_N, F_P, F_R and F_L
L: from "The Physics of Skiing" (Lind a. Sanders, 2004) R:MP



Difference between the calculated, ideal exit speed and the measured exit speed for a trajectory of the world cup SuperG
Own presentment



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Subject Area
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