

Interacting with Outdoor Sports Performance Data

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ABSTRACT

This paper presents a portable application to visualize performance data obtained from GPS devices in outdoor sports (e.g., ski, running, BTT) that also record data as heartbeat rate. GPS file formats are analyzed and a data structure that enables easy and flexible data manipulation is presented. Several data representation (chart, map and table) and visualization issues are addressed. Results show that the set of interaction design requirements was appropriate. The application is portable to due the development tools adopted (OpenGL, GLUI and TinyXML).

interaction, visualization, interface design, data display

1. Introduction

This paper presents the current status of an application designed to carry out the visualization of data collected by GPS based devices capable of recording data other GPS data (e.g., heartbeat rates) and compare data from the same athlete or by others in the same or at different occasions.

The application operates under Microsoft Windows and Mac OS and is portable given the adoption technologies like OpenGL and GLUI [Rad99] and portable libraries such as TinyXML^{*}, libJPEG and libPNG.

The application gets data from files written by devices with the recording formats such GPX (GPS Exchange format), TCX (Training Center Database XML), SDF (Suunto Data Format), CSV (Comma Separated Values), Waypoint Plus and others.

1.1 Motivation

In sports where the time taken to run a course is the main issue, a stopwatch was first used to compare different runs or athletes. Trainers then started taking partial (lap) times. Next, events organizers, and later sports broadcasting, added speed guns in sports where speed was an issue. Car racing went completely into full data collection and, in the case of Formula One, full telemetry that was later partially banned by its governing body (FIA).

Alpine Skiing World Cup events went from almost no data collected (or broadcast) to times and speed guns at selected points in the runs. Such data is broadcast on TV and the Internet but not retained. The hardware for partial times and measuring speed is expensive and not easy to set in place and therefore its use remains restricted to major events.

In ski course setting, start and finish locations are set at well-known locations and used over and over again. Course data like vertical drop, start and finish altitude and course length are known in advance. Setting a new start or finish location is not straightforward and involves a lot of work, even with digital land survey data.

The International Ski Federation (FIS) set up the Injury Surveillance System, which has collected race data by fitting GPS devices and other sensors to race forerunners [FIS11]. Such experiments target racers' safety through equipment survey and improvement and not racing performance and physical conditions.

Wagner Custom Skis and Snowboards[†] started fitting sensors to probe skis. These sensors (vLinks) are enhanced optical mice that collect data at a rate of 6500 data points per second. After testing with a customer, data is uploaded from the sensors to a proprietary software application to get ski-manufacturing parameters that best fit the each individual customer [VEA11].

Recent developments in off-the-shelf devices have made it possible to start collecting performance data for performance analysis at prices not exceeding €300 per recording device, but simultaneously raise the need to address some problems posed by the data that needs to be recorded.

2. Data recording devices

Data recording devices, especially wrist-held GPS devices, combine GPS features with heartbeat rate acquisition, show increased functionality and robustness and the price reduction and less cumbersomeness. Equipment vendors bundle their hardware with software applications that, most of the time, only display the data collected over digital or Google or Bing maps. Data tables are rare. Performance analysis is reduced to overall data like time taken,

^{*} <http://sourceforge.net/projects/tinyxml/>

[†] <http://www.wagnerskis.com/>

distance run, average speed, total descent/ascent and, when heart beat rate is recorded, calories expended.

Some devices and applications (e.g., Garmin Forerunner 305 [GAR08]) include the concept of a lap, generally signaled to the devices by the press of a button. This is not practical in sports like ski racing and BTT downhill where there is no way to start and stop recording devices automatically and racers cannot do so manually. Therefore, analysis software must provide the user with some means to section the data collected.

Also, there may be long idle intervals between races or race practice runs (e.g., waiting for the start). Racers may pause recording devices to save on battery lifetime or device memory. All such idle times need to be removed

3. Data Acquisition

A racing run usually lasts from 30 seconds to 2 to 5 minutes. But a set of several ski practice runs may last a couple of hours and longer runs may last some 5 to 6 hours but then data rates need not be as high as for shorter runs.

Some devices are able to record at a rate of one data point per second [Bri10]. Rates below that produce unreliable data because devices compensate such slower data rates (Figure 1). The straight chairlift section path fits pretty well with the actual travelled path, but the remaining path shows remarkable deviations from the likely travelled run path (white area). The device used, a Suunto X9Mi, recorded position and speed at 10s intervals. The sampling rate was not enough. The distance (1.5 km) took 4:31 minutes to run but only 17 data points were recorded when some 29 points should have been recorded at 10 s intervals.

4. Navigating the Raw Data

With proper data acquisition rates, users find it difficult to navigate the recorded data and get useful information due to its volume. Visual data table inspection of the data of Figure 1 located the start and end points easily because only 44 points were recorded. But examining a data table with 1345 data points (see Figure 2) is too cumbersome and takes too long.

Comfortable identification of the number of relevant runs could only be done using the chart on the right of Figure 2 with a plot of altitude versus time where it seems that there are 3 runs, but only the first two are relevant because the third one is just the return to base.

This means that software should enable users to locate run start and finish and isolate the data between from the rest of the data (see Figure 3). Two different colour lines show the two runs from run start to chairlift start. The last common location of the two runs after the start is a likely candidate for the finish (shown by the black vertical line).

5. Data Variables

Section identification by colour would be appropriate but other variables besides location and altitude should be considered: speed, distance travelled and heart beat rate. Instruments may also produce derived data from the raw data as climb (or descent) rate, hill grade and calories expended.

This means that colour or another key (e.g., dashed representations, line thickness or symbols) is necessary to make chart reading easy. Otherwise, charts will be almost unreadable (see Figure 4).



Figure 1: Path recorded showing significant location errors from the actual path (white area) due insufficient data collecting rate. But the almost straight yellow section fits rather well with the (slower) chairlift actual travelled path.

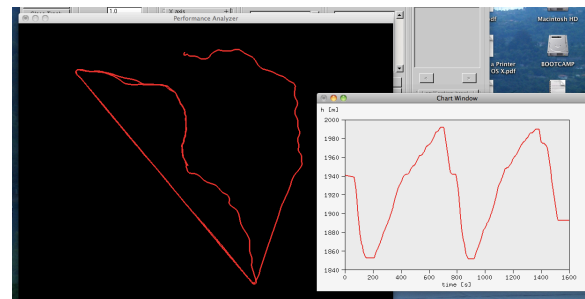


Figure 2: Path recorded at 1 second intervals. The number of runs cannot be deduced from map (left). Altitude vs. time chart (right) allows the identification of three runs. Total time: 26 minutes and 36 seconds; 1345 data points.

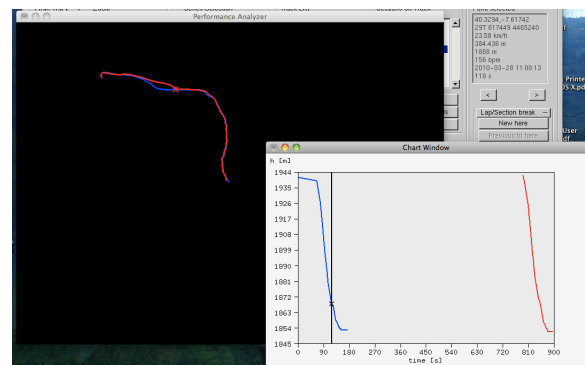


Figure 3: Two relevant sections of the path of Figure 2 after identification of the start area and before identification of the finish area. The vertical black line on the chart is an approximation to the crossing of the finish line given the last common point of the two track sections.

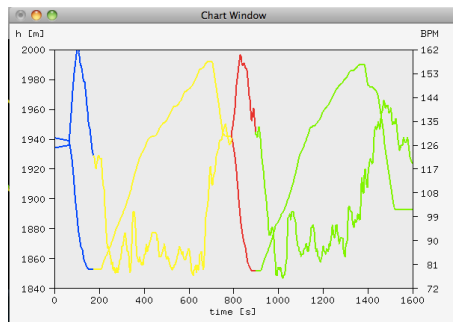


Figure 4: Chart showing altitude and heartbeat rate in several colour identified sections. However, the lines corresponding to the two variables are not easily identifiable.

6. Data Representation

6.1 Data Formats

GPS data (position and altitude) uploaded to applications is usually exportable to file data formats such as NMEA RMC[‡], CSV[§], SDF^{**}, TXT or Waypoint Plus formats. Suunto devices also record altitude as measured by the devices' altimeters in a file section at the end of the file.

The KML (KMZ) data format is a XML based format with data representation enrichment capabilities (see Figure 5), at the expense of data duplication. But these features provided are immensely useful.

6.2 Advanced Data Formats and the Lap Concept

The GPX (GPS Exchange) file format presents the lap concept. The format supports a sequence of time ordered lap sections (designated as track segments), each containing global data and time ordered data points. But GPX format was not intended to store data such as heartbeat rate. This prompted some extensions to GPX, like the TCX (Training Center Database XML) or the Fitlog format from Geonaute.

6.3 Internal Data Structure and Interaction

Interaction requires that there be no data duplication to ease data error correction and segment manipulation. These way users are able to:

- Correct data values
- Eliminate redundant data points
- Navigate the data set as a continuum
- Create / delete segments
- Move segment boundaries (start and end points)
- Change segment visibility and other properties

A GPX based modified data structure was adopted.

[‡] National Maritime Electronics Association.

[§] Comma Separated Values.

^{**} Suunto Data Format.

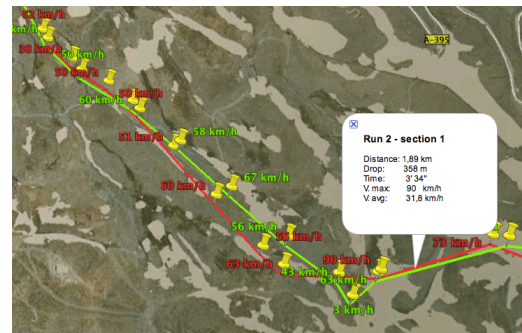


Figure 5: Google Earth of data enriched tracks showing speed at selected locations. The KML file was extensively edited to provide the data display facilities shown.

7. Data Representation and Visualization

7.1 Table View

This simple way to display data is effective when there are no more than 30 or 40 points but is necessary to be able to inspect values in some already identified sections. The present version of the software does not yet support a full table view. Rather it uses a simplified table view where only a data point is shown at a time (Figure 6, top right). Controls below the simplified table view allow scrolling left (previous points) or right (later points). The simplified table view is connected with the chart and the map views.

7.2 Map View

Many current map view representations use Google Maps services to display track data. However, there is also demand for the support of digital or digitized survey maps that add other kinds of information not available from Google or Bing Maps. Figure 7 shows the display by our software of a military survey map over which a course track has been plotted.

7.3 Chart View

Chart view is important to identify important locations in a track. On Figure 6, chart view allowed the rapid identification of the locations corresponding to the start of a run. In the case depicted on Figure 7 a pause in the course was identified by the drop in heartbeat rate.

Magnitude identification by colours in char view may not be enough when simultaneously displaying several sections as Figure 4 shows. A new key (e.g., dashing) has to be used to identify magnitudes, keeping colour to identify sections. This is still a subject for trials a tool for colour, line thickness and line dashing (see Figure 8).

7.4 Other Features

Currently, the application displays three windows at the start: the command window, the map window and the chart window (see Figure 9). The simplified table view window is included in the command window for the time being. Figure 10 is the same as Figure 9 with the properties window showing the summary data for the currently section.

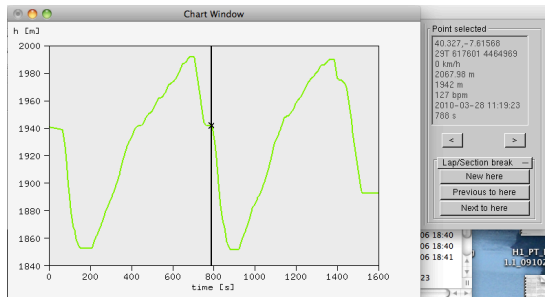


Figure 6: Simplified table view (top right) with values of a point identified on the chart view (left) by a black vertical line. Two buttons below table view provide navigation.

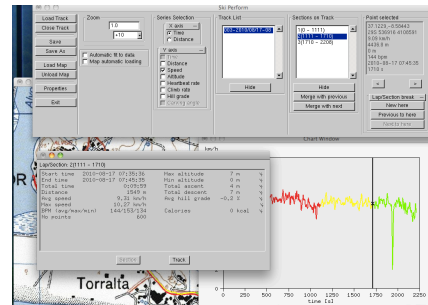


Figure 10: The properties window showing global data for the yellow section.

8. Further Developments

Alternatives under consideration to compare several runs comprise side-by-side representations on a sector-by-sector basis. Runs could be shown in parallel on map view. Parallel animation is also being considered as well as the adoption of dynamic time warping (see [MR81] and [KP01]).

Finally, it is envisaged to support multimedia documents, especially photos and synchronized video that, when shot together with data recording, can provide a lot of information and cues for improvement of sports practice.

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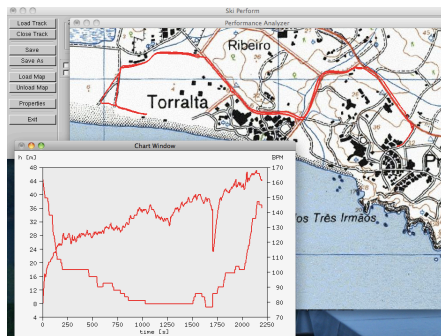


Figure 7: Track representation on a military survey map. Chart view shows altitude and heartbeat rate.

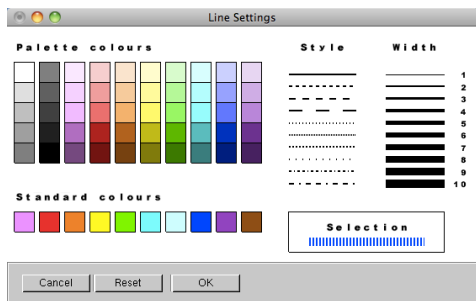


Figure 8: Line properties selection tool interface.

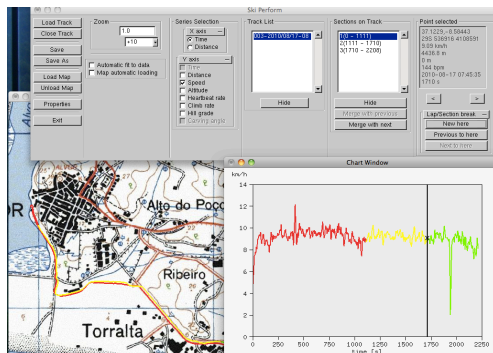


Figure 9: Current application interface showing the command bar, chart view and part of the map view.