Designing Interaction
for Outdoor Sports Performance Analysis

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Abstract

This paper addresses the design process of the interactive features required by the users of an application to support athletes and coaches engaged in outdoor sports in analyzing sports performance other than pure fitness. Devices recording position and heartbeat rate allow raw data acquisition for this analysis, but existing software functionality is limited. The paper addresses the collection of interaction requirements for the application to develop that followed a user centred approach with role-playing, interviews, focus groups, scenarios and usability experiments with users involved in outdoor sports practice and competition. The work assessed issues relating to data acquisition, correction, analysis and presentation as well as data persistency and user profiles. A comprehensive set of interaction requirements are then identified and analyzed. Candidate solutions currently being implemented and tested in a full-scale prototype are presented.

Keywords
Interaction, design, sports, performance, data analysis, data acquisition, mobile computing.

1. INTRODUCTION

Developments in outdoor sports data collection devices have increased the range of possibilities of sports performance analysis. This is largely due to price reduction, increased functionality and robustness, and reduced cumbersomeness.

However, the software to analyze and display the huge amounts of data so collected is still a long way from satisfying user needs beyond simple physical fitness analysis.

Cardiac data acquisition and recording has gone from mere instantaneous heartbeat rate display to sampled at regular times heartbeat rate recording and transmission. Simultaneously, wrist-held GPS devices, which record time, position and altitude, have merged into one single device with heartbeat rate recorders. This enabled outdoor sports practisers to gather more precise and comprehensive data, thus opening the way for better data analysis of sports practice and competition.

Equipment vendors know that data upload from devices and basic data display are not enough to differentiate themselves in the market and thus bundle some software for data analysis and storage with devices sold. However, this software is limited because it is usually given away with the devices (or available from the Internet) and thus cannot support the wide (and, sometimes, incompatible) full range of requirements set by different outdoor sports.

Some vendors provide sites where users can register, store data and make some (reduced) visualization and analysis. Some sites allow data sharing between users, and thus set virtual communities. But each site operates only with data produced by devices from a given vendor. Thus, end users have to do with limited capabilities software that may even not accommodate their basic requirements.

Furthermore, end users in informal sports groups or at club level, who do not use devices from the same vendor, are unable to share data and make comparisons other than the most basic.

The above shows the need to reassess the issues involved and propose a new design for an interactive application supporting sports performance analysis.

1.1 Objectives
The objectives of the work reported here were:

- Analyze significant devices available on the market and their software.
- Identify interaction and user requirements that were not met by existing software.
- Discuss issues related to interaction requirements identification and solution design.

1.2 Contents
First, this paper addresses the methodology that was adopted, and then analyzes data recording devices available on the market and the software available with them. This is followed by a discussion on data, raw track data and user data. Data correction is then addressed. Finally, the main features' requirements are presented with results and conclusions.

2. METHODOLOGY

A user centred methodology was followed because most users, although knowledgeable in the specifics of the sports they practice, have little to no knowledge of sports data collecting devices and how to process the data collected. The application to develop had to be simple to use and its added value had to be made clear to users.

2.1 First Phase

The approach started with a series of projects of the User Centred Design course at IST carried out by students as the main course assignment. Starting with identical objectives, students were given the freedom to conduct the project as they saw fit and explore the solution domain at will. For this they conducted inquiries, interviews and experiments with users, individually and from focus groups. Cultural probes ([Gaver99], [Anderson04]) were also used. This involved some 30 users (amateur athletes, athletes, coaches and MDs) in various phases.

Students explored the problem domain from devices to collect data to the operation of the application, searching for alternative designs, following the methodology of [Sharp07], and collected usage scenarios.

The result was a set of requirements tentatively implemented in several prototypes that were explored with users. The tests allowed prototypes to evolve and be tested with users in controlled usability experiments.

The main results from this phase were:

- A set of requirements for the functionality of the application to develop
- A set of interactive solutions to support user requirements

Without knowing it, the students involved in the projects were part of the user experiment themselves because they were allowed to try any approaches and solutions without a definite background. Observation of student activities reporting in class seminars was very important because it allowed us to pinpoint difficulties and pitfalls in the process of the application development and testing later on.

2.2 Second Phase

The second, and current, phase had the objective of producing a working prototype and testing its components. This involved data collection on the field, data upload, conversion, data storage, data filtering and correction and analysis.

With the help of the members of the National Kids Ski Team we collected data at the 2010 La Scara International Championships and at the National Alpine Ski Championships (Slalom) and the Spanish National Veterans Alpine Ski Championships. Others contributed with data from cross-country and jogging activities.

The tests involved getting raw data in various formats into the application together with maps (both from graphics files or from interactive sources, e.g., Google Maps) and produce visualizations to be interactively used in data validation and analysis.

Of course, this involved testing with users, with special focus on the steps of getting data to the application, data correction and data display and manipulation.

2.3 Next Phases

The current phase will be followed by two more phases: platform selection and final implementation and testing.

The current prototype has been implemented for MS Windows in C#. This choice of platform prevents the application to be used in other popular operating systems like Mac OS, a limitation that is common to the software of most device vendors.

Furthermore, portability means supporting the solution for graphical data display on a portable graphical system or package, like OpenGL [Woo99] or GTK [GTK10], with user interface support, and the selection of a programming language, like C++. These options must be evaluated on the face of the exact functionality requirements set by the results of the second phase prototype experiments.

The final phase will involve building and testing the final version with users.

3. DEVICES AND ASSOCIATED SOFTWARE

Data for sports performance analysis originates from devices carried by athletes while practicing or competing.

Vendors usually provide software for data upload to a Windows PC that, most of the times, does some data processing and shows textual summaries and data charts.

Next, we briefly present a few significant devices from some device vendors (Suunto, Polar, Garmin and Geonaute) and their software.

3.1 Suunto

Suunto was one of the first suppliers of wrist-held GPS devices. Suunto X9i [Suunto06] and, recently, X10i, record time, position, altitude (both GPS and altimeter) and speed at user preset intervals, but no heartbeat rate. This is a basic instrument whose minimum 10 seconds recording rate makes it more appropriate for slow speeds or long distances.

Both devices connect to Windows based PCs through a serial USB connection. They come with a Google Earth track upload program that gets the list of tracks stored in the device and, on user selection, creates a temporary KML[1] file, and fakes the Web download the file to Google Earth. The KML temporary file holds only track points' locations.

All data is only available with Suunto Trek Manager, a program that accesses the device and uploads and stores track data. This program can export track data in the KML, SDF[2] and TXT (Waypoint Plus) formats.

Trek Manager requires calibrated maps in common image formats (BMP, JPEG or GIF) to show tracks on Map View. Profile View shows altitude and/or speed versus time or distance. Track View shows data sum-

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[1] Keyhole Markup Language.

[2] Suunto Data Format.

maries as well a table with coordinates of all track points. These can be eliminated but not edited.

There are no user profiles and all data and maps are stored in a treelike directory structure.

3.2 Polar

Polar RS800 [Polar] with Polar G3 GPS pod and Polar ProTrainer software (Windows only) make up a very complete set aimed at physical fitness. Unlike most devices from other vendors, the RS800 connects to a Windows PC through an infrared IrDA USB adapter.

The software has complete user support, with very comprehensive user profiles and training logs and diaries, and fitness analysis, but this is totally built around heartbeat rate recordings and focused on fitness.

The program's charts show heartbeat rate, altitude, speed, cadence and power against either time or distance. Data error correction is restricted to the definition of the ranges of admissible values. Track sections definition or deletion is done as in audio or video track editing and force users to know start and end times or distances because no map view supports more advanced editing.

There is no Google Maps support, but the program can export data to Google Earth or save data to GPX[3] files.

3.3 Garmin

Garmin supports combined GPS and heartbeat devices with a lightweight application, Garmin Training Center, that runs on Windows and Mac OS and supports data upload through a serial USB connection. Data can then be uploaded to Garmin Connect, a website providing more advanced data analysis, user support and data sharing.

Both Garmin Training Center and Connect export data to Google Earth, GPX files and TCX[4] files, a GPX extension supporting timed-stamped heartbeat rate data [Garmin08].

Charts on both products display heartbeat rate, speed, altitude and altitude change as functions of distance, time since recording start or (unique to Garmin) absolute time.

However, data correction can only be made at the level of lap deletion (a lap is a very broad concept that may mean the track between two locations set by pressing a device button).

Garmin uses its vector GPS IMG maps to display tracks with Training Center and Google Maps with Connect. This allows Training Center to operate offline, while Connect can use Google Maps because it is already a Web application.

Data collection is done either at one-second intervals or every time the user changes direction (Smart Recording). The earlier has the disadvantage of filling up device memory too fast (little more than 3 hours), while the later may miss recording relevant data if the user travels on a straight line for a long time.

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[3] GPS Exchange format.

[4] Training Center Database XML.

3.4 Geonaute

Geonaute KeyMaze [KeyMaze] is a line of GPS wrist-held devices. The top of the line device (Keymaze 700) also records heartbeat rate at a user selected sampling rate that can be as low as one second. Data is uploaded through a serial USB connection to two Windows applications, KeyMaze 500-700 Utility and Geonaute Software.

Both applications rely on Google Maps to display tracks logged with devices. The Utility has no concept of user profile or activity type and displays only simple charts of altitude, speed and heartbeat rate versus time. Conversely, Geonaute Software has extensive user profiles and activity types and descriptions and its charts plot altitude, speed, heartbeat rate, pace and power against time or distance while allowing for other chart enhancements (see Figure 1). Both applications provide textual data (summaries), with Geonaute Software providing the most extensive and comprehensive.

However, there is no support for data correction and the comparison of data from different runs is rather limited on the Software and nonexistent on the Utility.

The Utility exports data to KML (and Google Earth), CSV[5], enhanced with heartbeat rate values GPX, NMEA RMC[6] and TXT files. GPX and TXT files contain all data; the other formats miss some of the parameters (e.g., speed). The Software exports only to KML, GPX and Fitlog formats and, as it is more physical fitness oriented, does not include all parameters (e.g., speed).
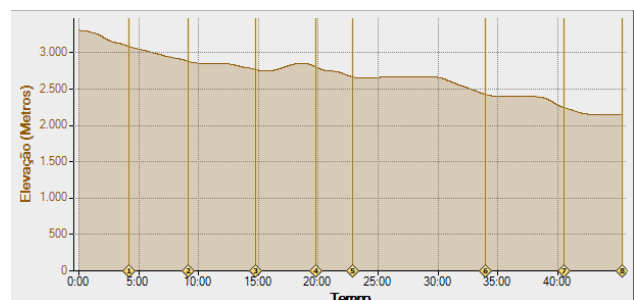

Figure 1: Altitude change with time. Speed is not shown; equal distance vertical lines provide indirect speed information.

3.5 Remarks on Devices and Software

The above shows different solutions for the analysis and display of data collected by outdoor sports oriented devices and the software bundled with them.

3.5.1 Chart Representations

In general, solutions target physical fitness objectives and completely forget the analysis of performance especially in sports played against the clock (e.g., mountain bike downhill, skiing) or where acrobatic aspects are relevant (e.g., wakeboarding).

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[5] Comma Separated Values, easily read by spreadsheet applications.

[6] National Maritime Electronics Association, Recommended Minimum data for GPS: position, velocity and time.

Chart representations invariably come down to the plot of one or more parameters versus either time or distance. There is no provision for more advanced correlations, like speed and/or heartbeat rate versus hill grade.

Figure 2 (altitude-distance) and Figure 3 (speed-distance) charts illustrate the above. All software displays any of the two charts, but only one at a time. There is no way to visually correlate speed with hill grade and how speed changes with hill grade. This would not be easy to plot on a speed and height versus distance chart since we would end up with a cluttered chart.
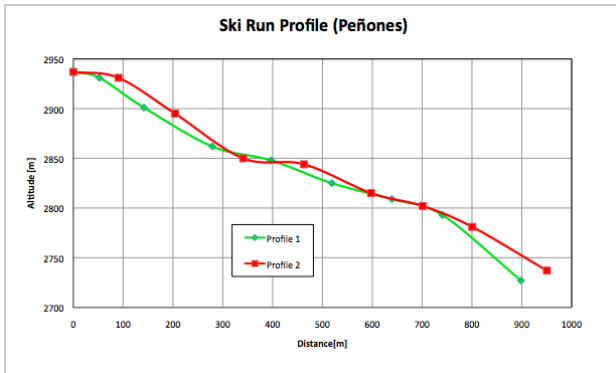

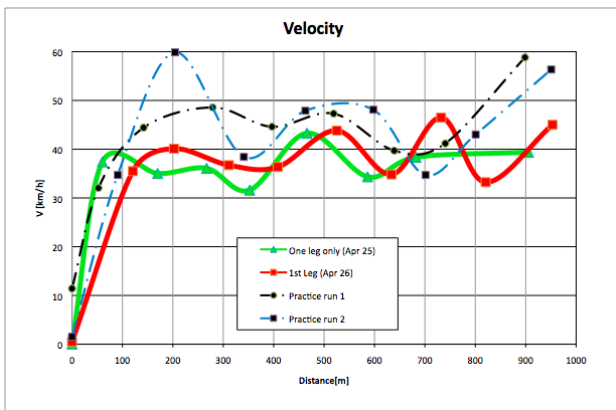**Figure 2: Altitude-distance approximate profiles of a giant slalom ski run.**

Figure 3: Velocity-distance profiles of training and competition runs on the ski run of Figure 2.

3.5.2 Section Identification
The concept of track sections and section-by-section analysis is rather vague. Most software define laps, but the concept can vary widely from laps around a race track, to passing repeatedly close to the same location (although very different courses may be followed in between passages) to a given time interval (every x seconds) or distance (every y meters). Furthermore, users must either signal lap completion by pressing a button on the wrist-held device (impossible to do while ski racing or wakeboarding) or accept whatever the software thinks a lap or a section is or has been set on the device.

The giant slalom ski run shown on Figure 2 has three different sections that must be differently skied. Therefore, it would be convenient to be able to analyze each section separately in order to better understand the run and improve timings. This shows the need for a feature

enabling users to interactively identify sections on a map, chart or data table.

Moreover, as in the case of Figure 1, we may need to assess the same track in two ways: the whole track or a special section of the track that begins 29.5 minutes from the start and ends some 5 and a half minutes later. This section was easily identifiable on a Google Maps view but it demanded some 15 minutes of data manipulation with a text editor and a spreadsheet application to get the approximate start and end times. This was because the application did not allow pointing to a location on the map view and immediately show it on the height-time chart or on the track points' table.

3.5.3 Data Pruning and Correction
The identification of sections would also enable discarding irrelevant data from data sets. This is the case of data collected while waiting for the start of a race, after the race (while the device is not stopped) or in between races (device not paused).

Data correction also needs the point-to-map-to-select-data to point to data that may contain errors (position, altitude, heartbeat rate) and start correction procedures (see section 5.2).

3.5.4 Data Comparison
To compare data from two or more passes that followed the same track one needs to be able to make apart the parameters that make the differences between the passes, especially in the cases of almost identical passes.

This is because there may instances when two racers are separated by fractions of a second after a couple of minutes or kilometres. Existing software would create map views and charts where data from one racer would be visually indistinguishable from that of the other.

Therefore, the software to develop must be able to detect such cases and revert to representations where track lines are artificially separated or, if coincidental, there is additional graphical information that clearly shows the little differences between passes or racers.

3.5.5 Data Enrichment
Sometimes one needs to publish or make a permanent representation of some track data (e.g., for informational or educational purposes). This is the case of Garmin software that produces Google Earth path animations.

However, it is much more important to be able to associate data to track visualization and turn it on and off. Figure 4 shows a Google Earth display of a KML file that was enhanced with speed value labels that can be turned on and off. Callouts display section summaries.

3.5.6 Multimedia Content
Suunto Trek Manager is the only software mentioned here that allows associating a position on a track with images and notes. All other applications lack this feature that can be of advantage, especially when images and video of different runners have been shot and may show errors or reasons for different performances.
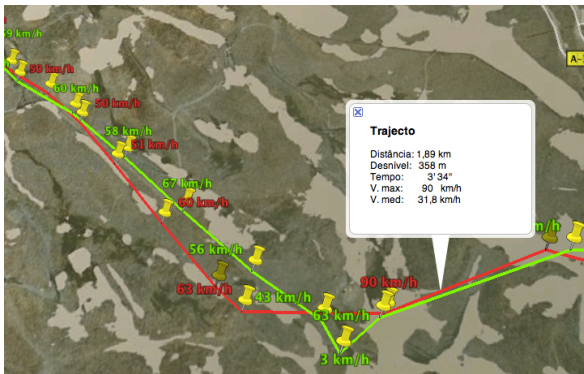
Figure 4: Data enriched tracks, displaying speed at selected track points by extensive manual enhancement of a Suunto Trek Manager generated KML file.

4. DATA

When asked what data to collect, users mentioned that the relevant parameters were: heartbeat rate, position, speed, calories burned and hill grade. Some mentioned altitude as next most relevant, followed by, in decreasing order of relevance, climb/descent rate, ambient temperature, blood pressure and sweating rate. Except once, no users ever mentioned data sampling rates as an issue.

In general, users confused parameters measured by devices with parameters displayed by them but computed from the earlier (e.g., hill grade was often mentioned but altitude was not) and forgot time most of the time.

Almost all users mentioned that they would like to be able to choose the data units to be used. They emphasized that choice of data units for speed, hill grade and climb rate were essential.

However, users never mentioned choice of position coordinates units as an issue, thus showing that the majority is not aware of the existence of many such units (UTM, geographic units or others) or that many maps use local geographic coordinate systems and grids instead of a unique global coordinate system. This is because users are much more familiar with applications like Google Maps or Bing Maps than they are with survey maps.

4.1 Data Parameters Requirements

Given the above, the application to develop had to handle data of the following parameters (the actual parameters depending on the device used):

- Time (and date)
- Position
- Speed
- Altitude
- Heartbeat rate
- Blood pressure
- Sweating rate

Also, users should be able to select the units for each kind of parameter.

In what regards position coordinate systems, the application should use a global system with widespread use. The choice came naturally to the WGS84 datum. Any data in other systems should be transparently converted to this datum, especially maps (e.g., Portuguese military grid

maps) and users must be warned of that when loading new maps into the application.

4.2 Data Ownership and Sharing

Users made clear that data from each run should be associated with a specific user (its owner) and that it could only be shared with other users designated by the user, including granting access to coaches.

Sharing data was mentioned as important because it would bring in the social aspects of sports. Also, in many individual sports practiced in teams, there is the need to share information between team members to improve performance (first runners usually relay course information to team members running after). Most of the time there is the need to compare team members' runs.

Therefore, users needed to be able to grant/deny access on single and groups of runs data to single users or groups of users at any time. There was no mention of standing automatic access grants.

Users stressed that access granting must not be transferable.

4.3 User Profiles

To associate data with users (i.e., assign ownership) and keep and check access to other users' data, there must be a minimal user profile. There were opposite user opinions as to whether users must login or not, but the issue was settled when access granting was mentioned.

Furthermore, some personal data is needed to interpret run data. This is the case of indicative heartbeat rate values, especially maximum heartbeat rate and target heartbeat rate ranges for different types of sports practice.

Also relevant is the need to classify new data according to type of sport. A short list of the sports practiced by a given user is always better to handle than a long list of all possible sports. This classification brings in the benefit of a more logical structure for the set of run data of a given user and also helps in analyzing the data because parameters are not the same for all outdoor sports.

5. DATA VALIDATION AND CORRECTION

Most interviewed users and users from focus groups assumed that data collected by devices would always be correct. However, this cannot be assumed, especially in the case of position and altitude.

5.1 Sources of Data Errors

Position determination by GPS devices greatly improved after removal of the Selective Availability feature on May 1st, 2000, but errors remain. GPS devices need to receive signals from at least 4 satellites to unambiguously determine position. Natural obstacles (caves, mountains and trees), man-made obstacles (buildings and power lines) and even persons block signal reception. Proximity to water may also produce spurious readings.

Receiving antennae size is also a factor: hand-held GPS devices usually produce more accurate positioning than wrist-held devices. The later may even produce incorrect speed values on sudden arm movements (e.g., in a fall to the ground)

Figure 5 shows typical GPS position errors in the vicinity a power line in a narrow valley.

Figure 5: GPS position errors due to an overhead power line and mountain cluttered sky (all locations should have fallen inside the white area).

Altitude reading errors depend on device type. GPS altitude errors are at least double than position errors or higher. Altimeters require calibration before use or end up producing errors on the order of 50 m or more.

Altitude errors may not be as dramatic as position errors since, most of the time, analysis does not require correct altitude values but altitude differences where errors cancel out. However, some cases requiring correct altitude values still remain (e.g., start and end altitudes of a ski run for a race results list).

Heartbeat rate is not immune to errors. Heartbeat rate is usually acquired by fitting a sensor strap to the athlete's chest. Heartbeat rate values are continuously transmitted to the receiving device by small range weak radio signals. Tests done on a treadmill with two different recording devices show that devices usually display the same heartbeat rate but one is faster than the other to detect changes.

Errors occur when the sensor strap slips from its correct fitting position because there is too much sweat between the skin and the strap or the strap elastic fit loosens.

In both cases, heartbeat readings show a slowdown of heartbeat rate (because the strap is away from its correct position close to the heart). If there is no filtering, analysis may end up concluding that the athlete's performance has greatly improved.

Such events may be easily detected because there is a sudden heartbeat rate decrease that may go all the way down to rates close to or lower than the athlete's heartbeat rate at rest. Another sign is that this happens while there is no change to other parameters (e.g., speed remains constant). Also, the change is so sudden that it cannot be confused with the athlete stopping the exercise and going into recovery where a slowdown of heartbeat rate extends over several minutes in a decaying pattern.

5.2 Data Errors Correction
The above shows that the application interface must support tools to correct / eliminate the following main raw data error types:

- Position errors
- Altitude errors
- Heartbeat Rate errors

5.2.1 Position errors correction
Previously, we have seen that most software bundled with devices allows only two position error correction options: simple deletion of the location point or track section (or lap) where the error occurs.

When it is possible to change location coordinates, speed should also be changed because location and speed are interrelated. Moreover, software from device vendors has seldom the capability of directly point to and select a location on a map to edit its parameters[7]. None has the capability to detect locations where position or speed might be wrong.

This generated several requirements. First, the user should be able to select a location on a course, be it on a course map, a table of track points or on a chart of course parameters. If more than one of these views are simultaneously present on the application screen, selection of a location on any one of them must immediately be shadowed by highlighting of the same location on all others.

Second requirement was that the user could displace any location by a drag-and-drop operation on a course map. Naturally, all other representations of the dragged point should be updated accordingly.

The third requirement concerns automatic detection of location errors on the assumption that sharp turns are unnatural unless there is a pause in the course. Sharp turns may be detected by assuming that course tracks are smooth and any point not close enough to an assumed smooth track is a candidate point for inspection.

Lastly, once a candidate point has been selected for position correction, a hint (based on the smooth course track assumption) for the new parameters of the location should be displayed.

5.2.2 Altitude errors correction
Correction of altitude errors can be made against analogical or digital references, on the assumption that location errors are negligible or have been corrected.

While altitude correction against digital references poses no major problem if interpolation is handled with care, altitude corrections against analogical references (i.e., maps showing altitude contour lines) is a different matter.

One way is to correct the altitude of a small number of locations, followed by the interpolation of altitude correction to the remaining locations.

For a single location, the procedure involves selecting a set of points that surround the location and are over altitude contour lines on a contour map, and letting the software carry out altitude interpolation using those points.

For exact altitude values, Web resources like Google Elevation API may be used.

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[7] The same requirement applies when selecting points for data values enrichment to be (selectively) displayed with course plots (e.g., on Google Earth, see Figure 4).

5.2.3 Heartbeat rate errors correction

Heartbeat errors correction is the most difficult to perform since there is no reference to get correct values from. The simplest way is to do away with the wrong data and assume that heartbeat changes smoothly with time and that sudden changes are errors. Provided that exercise effort remains unchanged, data can be assumed as back to normal when heartbeat rate returns to levels close to those registered prior to a sudden drop.

6. MAIN REQUIREMENTS

Given the above, the most relevant requirements for an application for outdoor sports practice performance analysis and evaluation can now be presented.

- Application to run without Internet connection. The application must run without connection to the Internet and display track plots to allow it to be used on the field. Track plots will be superimposed on a map if appropriate maps exist in the system and the user selects to use them.
- Three data view modes. Track data will be displayable in three modes: map view, chart view and table view. All three views may not be simultaneously displayed on the screen. More than one chart may be displayed at the same time.
- Map view, chart view and data view will display all data selected by the user irrespectively of whether it is the data of a single raw data set or section or a group of raw data sets or sections.
- Data comparison. When comparing almost identical data, map view, chart view or data view shall use display enhancements to make out or visibly amplify differences between the data sets that are being compared. On map view, a track may be placed parallel to its original location or visualization enhancers used.
- Progress views. When comparing data to assess progress, the application shall compare data sets in chronological order and highlight differences.
- Zoom and pan on maps and charts. Zoom and pan will be available in map and chart views.
- Choice of parameters to display on charts. Users will be able to select which parameters to display on a chart from all parameters in the parameter set.
- Location selection. When more than one view is presented on the screen, selecting a location in one of them will highlight the same location on the other views.
- Selection on map view. The location of a track point on a map closest to the pointer will be always the candidate location for selection. Callouts showing relevant track point data parameter values may be used at user's choice.
- Weather information (user supplied) will be attached to each new raw data set. Sections will inherit such weather information.
- Section identification. The user will be able to identify one or more (contiguous or not) sections in a track. Sections may be assigned visible or invisible status or be deleted. The user will be able to classify complete tracks or sections as good or bad examples and support this classification with multimedia content (see below).
- Error correction. The user will be able to edit the properties of locations or remove locations from a track data set. Editing will follow the guidelines set in section 5.2.
- User defined locations. The user will be able to add, modify and delete user-defined locations (markers) and associate them to a track data set to document events such as mistakes, accidents, etc. The user shall be able to associate multimedia content to marked locations (see next).
- Multimedia support. Users shall have the option to associate multimedia content (text, notes, images and video) to any locations and user-defined markers. Sections will inherit multimedia content from parent sections / raw data.
- Extendable parameter set. In order to allow application expansion to support user defined new parameter types (both raw or derived), the parameter set must be extendable by user customization and a tool should be available to help define new parameters and their units.
- Data structure, persistency and protection. The application shall keep all data in a treelike structure and regularly back it up. The user must doubly confirm data deletion and the application shall keep a copy of the deleted data for a given time set by user preferences.
- Data import. The applications will only import data from files produced by the programs released with the devices, thus committing the task of data upload from devices to vendors' applications.
- Data export. The application shall be able to export a full data set, a section, a group of data sets or a group of sections selected by the user in the extended file formats (GPX or TCX) and formats suitable for publication (CSV, tabbed text files, HTML tables).

7. CONCLUDING REMARKS

The methodology followed to determine interaction requirements needed by an application for the analysis of outdoor sports performance proved to be adequate and up to the task at hand. In fact, it was possible to identify many essential interaction requirements that are overlooked by software bundled by vendors with devices for data recording.

This was the outcome from adopting several complementary techniques of addressing users and user needs: interviews, role-playing, user groups, user focus groups, scenarios, usability testing and surveys.

The extensive set of interaction design requirements reported earlier has already produced results that are shown on Figure 6 to Figure 9. These results depict several solutions for the interface that were tested with users.

Work is progressing on the full-scale prototype. It is already possible to load data and maps and evaluate solutions for the interaction requirements (see Figure 9).

Figure 6: A solution for track display on a map and a chart, featuring a callout with data of a selected track point.
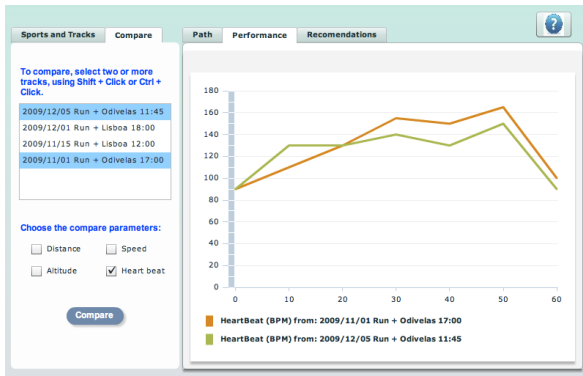

Figure 7: Solution for data selection and simple comparison of data from two runs on the same track course.
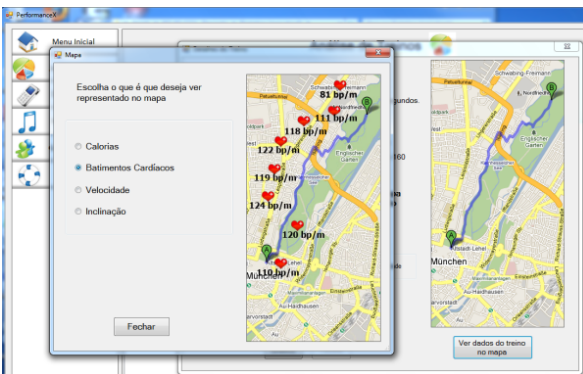

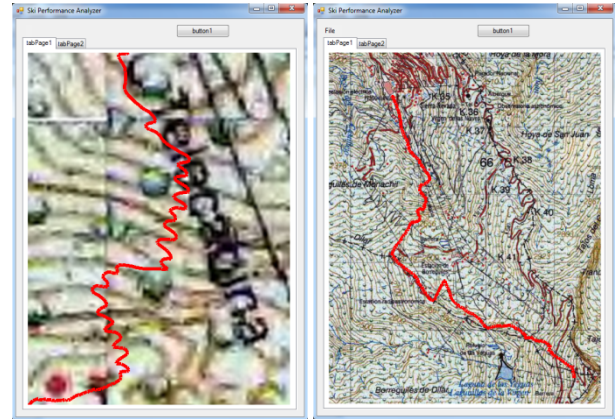**Figure 8: Solution for data enhancement on map view, showing heartbeat rate at selected locations.**

Figure 9: Data selection tests where zoom and pan on the track of Figure 1 on a map (right) allow the identification and isolation (left) of an important section.

8. ACKNOWLEDGEMENTS

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