ANALYSIS OF ELEVATION DATA WITH TIME ASPECT FOR ATHLETES

Rostislav, NÉTEK[1], Jaroslav, BURIAN[1]

[1]Department of geoinformatics, Faculty of Science, Palacký University, Olomouc, tř. Svobody 26, 771 46, Olomouc, Czech Republic

rostislav.netek@upol.cz , jaroslav.burian@upol.cz

Abstract

This paper presents specialized analysis based on 4D data for athletes. Generally the data received from GPS (Global Positioning System) devices contain elevation, spatial and temporal aspects. This type of data allows localizing current position of athlete in every moment. Evaluating and planning performance for professional athletes is based on elevation data primarily, because just elevation plays very important role for evaluating and planning for professional athletes. There are many variables in different sports which are tracked and monitored during the performance; like cadence, power, speed, heart-rate and many others. All of these variables are closely dependent on both elevation and time, and periodic monitoring is strictly required for training. There exists some specialized software which enables complex analysis of telemetry data from athlete's sensors depending on elevation with possibility of visualization in tabular, attribute, 2D or 3D graphic form.

The paper discusses different types and restrictions of elevation data received from GPS devices, especially possibilities of analysis which are really used by professional athletes and real experiences with using Garmin Edge 800 and Forerunner 310XT devices as well. Created application for upload data in GPX and/or KML file for visualization elevation data in time line is described. The application is based on interactive elevation profile, which allows analyzing information in 2D, 3D or 4D point of view, with manually and automatically shifting in time. For every moment are available elevation and other dependent variables shown in graphic, attribute and spatial form with focus on altitude.

Keywords: elevation data, sport, web application

INTRODUCTION

There are many fields, where elevation data are recorded and analyzed nowadays, because in last few years GPS devices are widespread for common users as well as for experts. GPS sensors are implemented in lot of kinds of equipment; users can record their route by mobile-phones, laptops, tablets, watches, cameras and of course by standard GPS receivers. In most cases the data are used, analyzed and visualized only in three dimensions, where on X and Y axis is captured horizontal location, and Z axis contains vertical value (in other words the elevation). In fact not only 3D data are captured, because all GPS devices allow 4D data capturing. The last fourth dimension means, that data are captured in some predefined time period, and typical positioning data can be analyzed also in time in addition. Actually, the sport is typical field in which analyzing data in time-line is very necessary. In addition there are many variables used in different sports, which are monitored during the performance, like cadence, power, speed, heart rate, temperature, wind-speed and many others. It means that athletes can evaluate tracked values from sensors in every moment of activity, and compare each activity with others (for example the same route during the year). The elevation plays very important role because power of athletes in every sport activity is strictly dependent on elevation profile in time. These analyses are very important for evaluation trainings and/or races with aim to improve the performance in the future. Only elevation data with time aspect gives possibility of objective evaluation, which is only one way to success for professional athletes nowadays.

REVIEW OF GEOSPATIAL TECHNOLOGIES FOR SPORT

In the last few years we have seen a huge boom in the using of modern geographic information system (GIS) and geospatial technologies (GIT) for sport activities. On the other side, it is still not much

widespread like in other fields (compare with traffic, military, archaeology or geology). The most common use (tourism, cycling, sailing, orienteering, rally, in-line skating, cross-country running, hiking, aviation …) of GIT is navigation and/or tracking routes by GPS devices during the trip. The Internet is currently the most widely used medium for sharing information, so the other use is upload and share source data into specialized map application like e.g. OpenCycleMap, MapMyRide or Service Garmin Connect (2011), with focused on both spatio-temporal and elevation component of data.

The location-based service (LBS) gives geospatial information, where geospatial means that it is based on the current geographic location. In all fields of human activity, including leisure-time activities and sport, is possible to localize position in time and tracking the movement. The sport gives us great opportunity to implement modern technologies like LBS and make some scientific research, because in every kind of sport is possible to analyze some movement of athletes (Ahtinen et al. 2008, Antikainen 2006). There exist many advantages why to track athletes – analyze and evaluate their training, locate their position in unknown surroundings, protect their safety, check their physiological characteristics because of health and obesity reasons or increase attractiveness of TV broadcast. The main principle is to locate the athletes by GPS sensor with high precision and to transmit consecutive data into spatial database. Data can be transmitted by Wi-Fi, GSM, SMS or modem in real time, which allows displaying position of athletes in real-time on screen (Brown 2007). Loggers have internal memory, which allows downloading data from device later into computer. In current years GPS tracking is more and more implemented in all kinds of sport. It is integral component of present sport activities all over the world.

Professional vs. amateur sport

From the principle of sport, this issue can't be viewed integrally, but it is also necessary to separate recreational and amateur sports with a genuine professionals. Professionals have a lot of possibilities to use the latest technologies and products, which are often very expensive and not available for the public. Selected professionals are often so called "testing racers" for example in the skiing, the cycling, or the Formula 1 drivers. They are testing prototypes of equipment, which is made in only one or several pieces in special version. Only on the results of these testing companies decide about the future of product development. The professionals have often access to extra function and/or tools which are not available in standard mode. This serves especially for testing and developing special devices.

In cycling, two of the best professional teams are sponsored by Garmin and HTC companies. The racers of Garmin-Cervélo Pro-Tour team and HTC-Highroad Pro-Tour team keep at disposal GPS devices about one year earlier than other teams, because Garmin and HTC companies testing their new devices just on team members. One season later, this device is available for other professional cyclists and earlier two seasons later, the same device is available in the shops for public. Generally at this moment the price is very high and it takes about two years to wide expansion into amateur cyclist. It can take about five years between the first use by professional and spread to the public. This is the reason, why focusing only at professionals athletes in this article is more relevant.

Role of elevation and time during the performance

In every sport the general aim is to be better and/or be faster than others. Because of physiologic aspect each person is different and each person has different presumptions for performance of course. Due to this individual distinction there are some physiologic variables which are measured by professional athletes. The most objective two characteristics are Power (in Watts; rate of work performed by an athlete in one moment) and Lactate (in millimoles per litre of blood; value of lactic acid produced by muscles during the performance), but both of them require very sophisticated devices. Often this kind of data can be captured it only in medical laboratories. Due to this reason is more often used heart-rate monitor (unit: Beats-per-minute) for everyday individual necessities, in addition to speed and/or cadence sensors in some kinds of sports (Figure 1).

The elevation plays most important role in measuring by sensors, because every of mentioned characteristic is strictly dependent on altitude and elevation changes – in higher elevation the power goes down, muscles produce more Lactate, depending on previous both the heart-rate value goes up, the speed goes down. Very

similar situation like increasing in elevation bring increasing in time of performance, especially in long-time endurance.

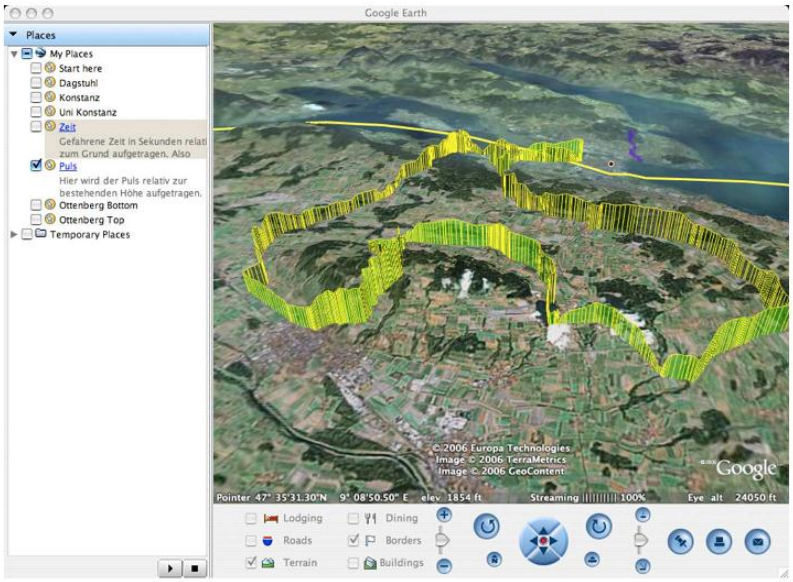

Fig. 1. Visualization of heart-rate values above terrain (Saupe 2007)

Cycling

A lot of cyclists use every day GPS receiver, but for professional riders are beneficial only connection with the speedometer, cadence-meter, heart-rate monitor and power-meter (see Figure 2). Only comprehensive data obtained from all these sensors allow professionals to fully analyze their training. The itinerary can be evaluated in the numerical statistics in a graphical time record, including tabular information on all measured variables for every moment (see Figure 3). Specialized devices produced by companies Garmin, Suunto or Polar are used in Pro-tour races. Especially Finnish company Polar (2011) is the world leader in heart-rate sensors. In every cases, the process of analysis of races output is allowed only by coherent multidimensional telemetry data received from GPS and other sensors.

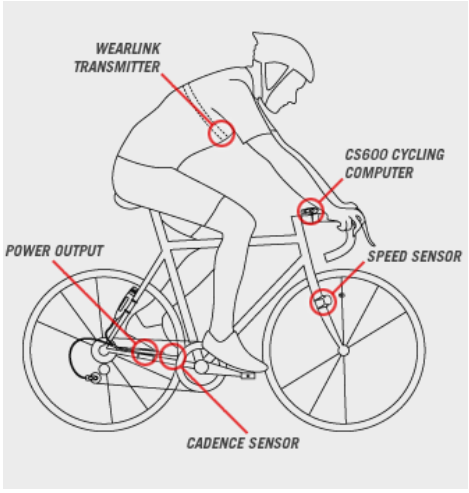

Fig. 2. Sensors used in professional cycling (Polar: http://www.heartratemonitor.co.uk/polar_wind_power_kit.html)

According to Saupe´s research (Saupe 2007) GPS device Garmin Edge recorded longitude, latitude and elevation simultaneously with other cycle sensors. Figure 1 visualizes heart-rate values above 2.5D terrain data for a 50km training ride in Switzerland. The heart rate is displayed as the height of the yellowish band along the cycling track. The output of heart rate, cadence, time stamp, longitude, latitude, and altitude per

sample is given in the form of an XML file. For the synchronization it suffices in this case to manually identify the time origins in both sequences and then to interpolate positions assuming a constant frame rate for the video. In this application time series synchronization allows replay of any given training session on the same training course, given a corresponding sequence of recorded GPS parameters. Moreover, for biofeedback experiments in the laboratory, computer controlled traction of an ergometer station can be accurately rendered. This setup could open a number of new possibilities for athletes, coaches and scientist (Saupe 2007).

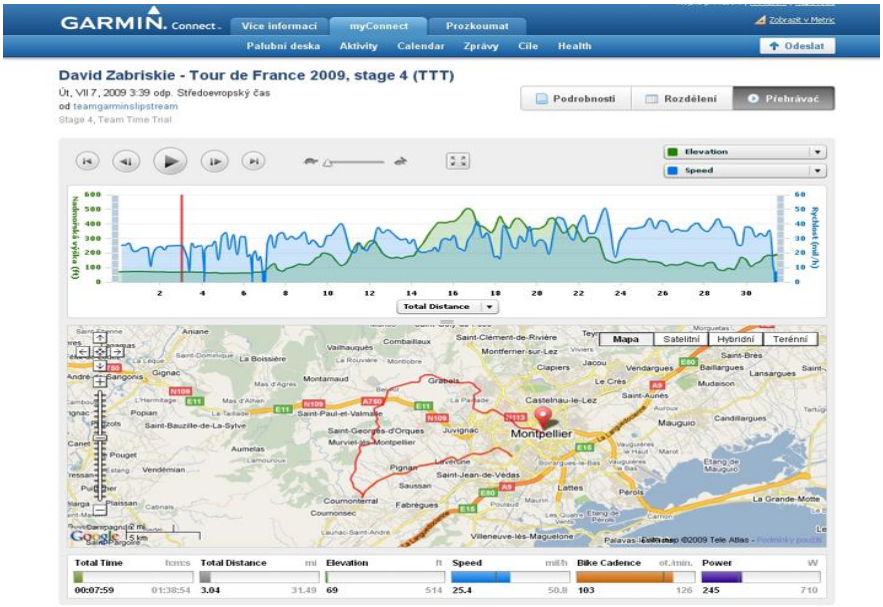

Fig. 3. Visualization of telemetry data, David Zabriskie 4th stage of the Tour de France 2009 (Service Garmin Connect: http://connect.garmin.com)

Some special devices allow so-called „virtual training partner" (Nétek 2010, Saupe 2007). The device can load another route file with both spatio-temporal and elevation characteristics (race of opponents and own race from another year) and the device shows deviations from the trajectory and time of the virtual opponent, in addition some stationary bicycle can regulate the resistance depending on elevation in real route (it means, that if in real route go up to hill, the stationary bicycle regulate the resistance higher, due to value of elevation in time). With synchronized video which is displayed at the same time with satellite images, is possible to simulate a real race track. It is possible to download all outputs from pro-cycling-team websites and simulate any route at your home.

Already established attractive technology is GPS tracking with real-time visualization on TV screen. Competitors are localized in real-time using the GPS chip and simultaneously are their position display on the TV screen. In addition to TV broadcasts, the technology is being widely used in stage races (Tour de France, Giro d´Italia, Vuelta de Espana, etc.), where visitors have opportunity to watch events on the big screens around the track or in TV at home. Competitors receive sensitive GPS sensor which capture data from GPS and other devices (heart-rate monitor, speedometer etc.) and stores it on SIM card. Then are data send via GPRS to the central server, which graphically displays the actual position, elevation and all other variables of the rider on the screen during live the races (Brown 2007). Figure 4 illustrates usage of elevation data with time aspect in real case. Beside real-time "2D" location of rider Maxime Monfort (yellow dot in map) and route of stage, there is actual position in elevation profile accompanied by actual values from four bicycle sensors (Speed, Power, Cadence, Heart-rate). The 2D/ 3D position of riders and all values have time aspect as well, because they are updated every two seconds. The only technical restriction can be surroundings of the rider (like dense forest), which eliminates the signal from satellites, but it is a minor disruption which takes only a few seconds, so on the screen is still possible compare leaders. In some special events the link can be combined with a video camera sees from helmet´s camera. GPS tracking for the "biggest" races is used since spring 2008, where was first time used at Giro d´Italia. During the Tour de France 2010, this technology was used for the first time such a general classification in real time. But it is

necessary to say, there are some special occasions, when it cannot be considered 100% reliable for classification. For example in 3rd stage of Tour de France 2011, had Lance Armstrong 3 defects in a single stage. In the case of emergency, riders with no ambitions give own bike to the captain, so Lance Armstrong rode more than one bike (with different sensor) during a stage. In all cases technology of GPS tracking is very attractive for fans (Yao 2008).

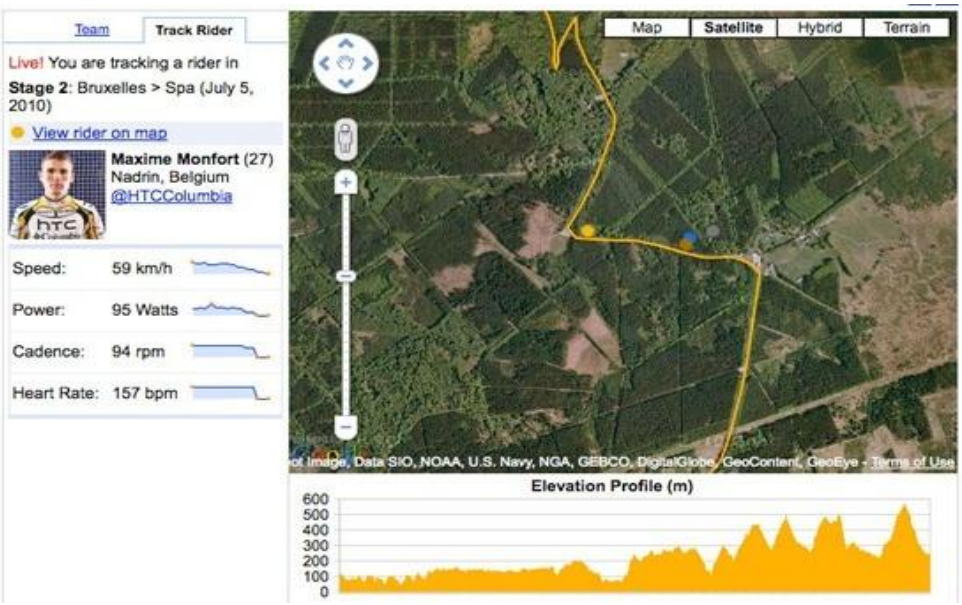

Fig. 4. GPS tracking – yellow dot indicates position of Maxime Monfort during the 2nd stage of the Tour de France 2010 (brown, gray and blue dots indicate other racers) (Nétek 2010)

Running, Orienteering, Cross country skiing, Inline skating

In the northern countries the orienteering is very popular outdoor sport. In this sport the issues discussed in this paper was used for the first time. The principle is very similar to the cycling, only with some technology restriction because orienteering take place in the forest. Also only selected athletes are equipped by GPS receiver, because competitors start in intervals, not all together at the same time. Because of this reason is not possible to use it for general classification in real-time, but it is very popular for screening the competitor's current position directly on the map. On the other side, there is great opportunity to analyze every part of run after the race and make complex analysis session (identify mistakes, time-losses, the reasons for the time-losses, better solution for the future, combination of different solutions etc.) (Zentai 2005). More than in any other sport branch in orienteering is elevation significant for athletes. Due to this reason, every application for visualization contains elevation profile.

In some running shoes is used technology for localization athletes by GPS shoe chip (miCoach by Adidas; and Nike+ by Nike). In both of systems is supported connection with Polar heart-rate monitor. Just complex data are valuable to analyze training by professional athletes. The advantages of the using this system is almost the same as in cycling. The runners need to evaluate attributes, because only comparing time/distance with their hear-rate in every second together allow them place for improving. There is function of virtual training partner and audio coaching by synchronization with mobile device. Based on predefined times/distance in every moment during route, the device compares your time/distance with "partner" and via mobile device give you signal about current situation.

There is a similar situation in sports like cross-country skiing or inline-skating. Nowadays the GPS tracking is required in a lot of competitions, but very interesting are applications built on a ski routes. Some volunteers or snowmobiles (vehicle which fixes cross-country routes), have own GPS receiver connected with thermometer and communicate via GPRS with central server. In the result, on the web application visitors can see completely up-to-date information about terrain covered by snow and weather conditions around. (Ahtinen 2008).

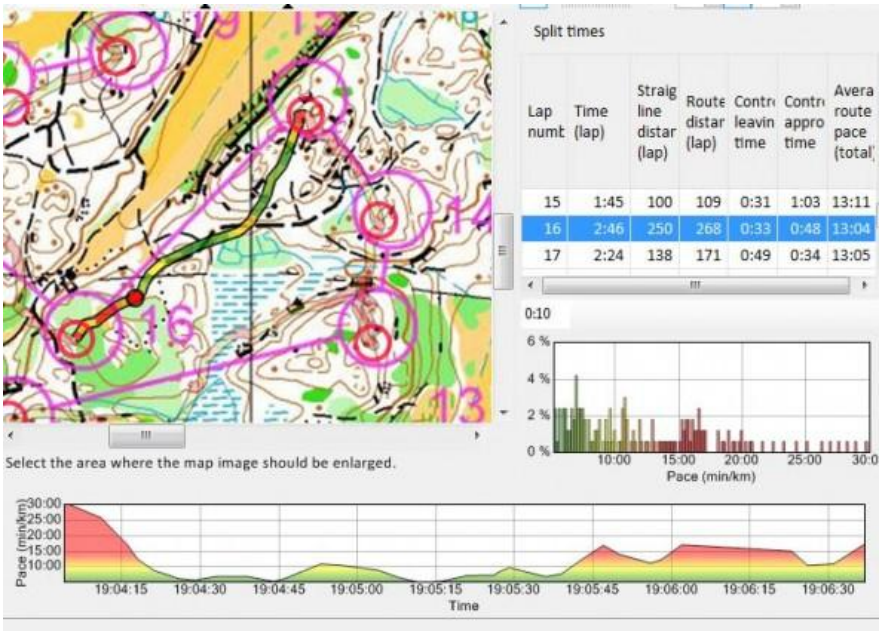

Fig. 5. GPS tracking output for orienteering (O-training: http://o-training.net/blog/2011/04/13/gps-analysis-for-orienteering-the-basics/)

Some special devices are used also for safe extreme skiing and ski-touring. Every skier has his own device (avalanche transceiver) that is used during the activity like active device (sender). In dangerous situation (avalanches) the device can be switched to the searching mode (receiver) and allows finding person trapped in avalanche. These devices use radio frequency. There are two basic transceiver types, analogue and digital. Digital devices give a range and direction; analogue devices provide an audio indication of distance and direction.

Sailing

Not orienteering, but sailing implemented GPS tracking for the first time at global scope. It was great to see live GPS tracking used in the Olympic Games Beiing 2002, where BBC made the first global broadcast with GPS tracking and show outputs in real-time on the screen. Today is GPS tracking on boats for navigation and because of emergency cases, however for comparing of boat trajectories is time-line very significant (Zentai 2005).

THE "PRAŽSKÉ SCHODY" RACE APPLICATION

The aim of our research was to create a specialized web mapping site, for organizers, visitors and racers, working with spatial and time aspects of real data on some real route in Czech Republic. The application is based on interactive elevation profile, connected with attribute information and photos in map field, moreover accompanied by video from biker's perspective. It allows analyzing information in 2D, 3D or 4D point of view, with manually and automatically shifting in time. For every moment are available elevation and other dependent variables shown in graphic, attribute and spatial form with focus on altitude. It was chosen "Pražské schody" race, which allows applying a lot of interactive functions. The application is available at: http://gislib.upol.cz/app/netek10/schody/map.html .

Elevation data

The "Pražské schody" race is the most attractive mountain bike (MTB) race in the Czech Republic, with an attractive downhill on the Old Castle stairs at the Prague Castle with the participation of the world's best cyclists.

Data were firstly captured by GPS device Garmin Edge 800 by one of the racer on the same route in previous year. Longitude, latitude and elevation in time with a resolution of one sample per second were recorded. It means that were collected real data from real route on real race!

Because one of the aims was to connect every edge-point with some attribute information and photo, original GPX file from Garmin device were modified into more than 30 edge-points To each of edge-point was manually added into database textual information and photo describing this place. Moreover, for each edge-point were automatically extracted or calculated from GPX file values of azimuth, partial and total distance, position into map field (for connection and synchronization between database and map) and two specific number values: elevation and time aspect. Elevation value ensures correct line of elevation profile (in GPX file it can be recognized by element <ele>). The second one, time value provides synchronization of profile animation with map animation in map field (recognized by element <time>). The data were stored in MySQL database on the server.

GPX File

All Garmin devices store recorded data in *.GPX files. There is great opportunity to use GPX files for spatio-temporal and elevation data, because of some typical elements. GPX (GPS eXchange Format) is an XML schema designed as a common GPS data format for software applications. It can be used to describe waypoints, tracks, and routes. Its tags store location, elevation, and time and can in this way be used to interchange data between GPS devices and software packages. Latitude and longitude are expressed in decimal degrees using the WGS84 coordinate system. Dates and times are not local time, but instead are Coordinated Universal Time (UTC) using ISO 8601 format (Wikipedia). The structure of GPX file corresponds to XML file, it contain some elements, like header or metadescription *(<metadata>* element) with some variables about the route. The main part of GPX file takes element *<trk>* and *<trgseg>* contains segment of route or whole routes, which is divided in particular edge-points called trackpoints *<trkpt>.* Each of trackpoint contains values about position and two characteristics about elevation and time (*<ele>* and *<time>).*

Fig. 7. Structure of GPX file with <ele> and <time> elements

Methods

In the application a range of technologies was implemented. Especially Google Maps API using JavaScript, PHP for dynamic pages generation, which communicates with MySQL database, and of course CSS and HTML for formatting own Web site were used. With Google Maps API is possible to create complex mapping applications using a combination of pre-programmed functions and/or scripts (e.g. JavaScript). This process is called a mashup. The result of this process is an application (so-called Web 2.0), which combines content from more than one source and allows the simultaneous use of different types of information and/or source combined together. This principle gives programmers the ability to create virtually low-cost applications, which are qualitatively comparable with the best commercial products. Besides the theoretical summary of the latest technologies using in cycling is the main result implementation these functions into real application. The application supports both KML/KMZ and GPX files for track, but because of native implementation of <ele> and <time> elements in GPX file, is better to use GPX file due to synchronization with animation.

Application

The prototype application demonstrates wide possibilities of the GI technologies. The application was focused and built on the interactive and dynamic elevation profile of the race, which is also linked to the map field. Dynamic means that profile can be run both manually and automatically as animation in three levels of speed. In the tools menu can be found in a wide range functions: deactivation/activation of layers (difficulty, type of surface, incline, critical points, critical points, audience sectors, parking), animation of track with information to the individual sections, export in 22 formats, "onscreen" search the route, an interactive itinerary and connected with animation and video tracks from the perspective of the rider, which simultaneously displays the location of the point on elevation profile, and in the map animation. There are administration possibilities with expanded functions to add/edit/delete other events and information about them.

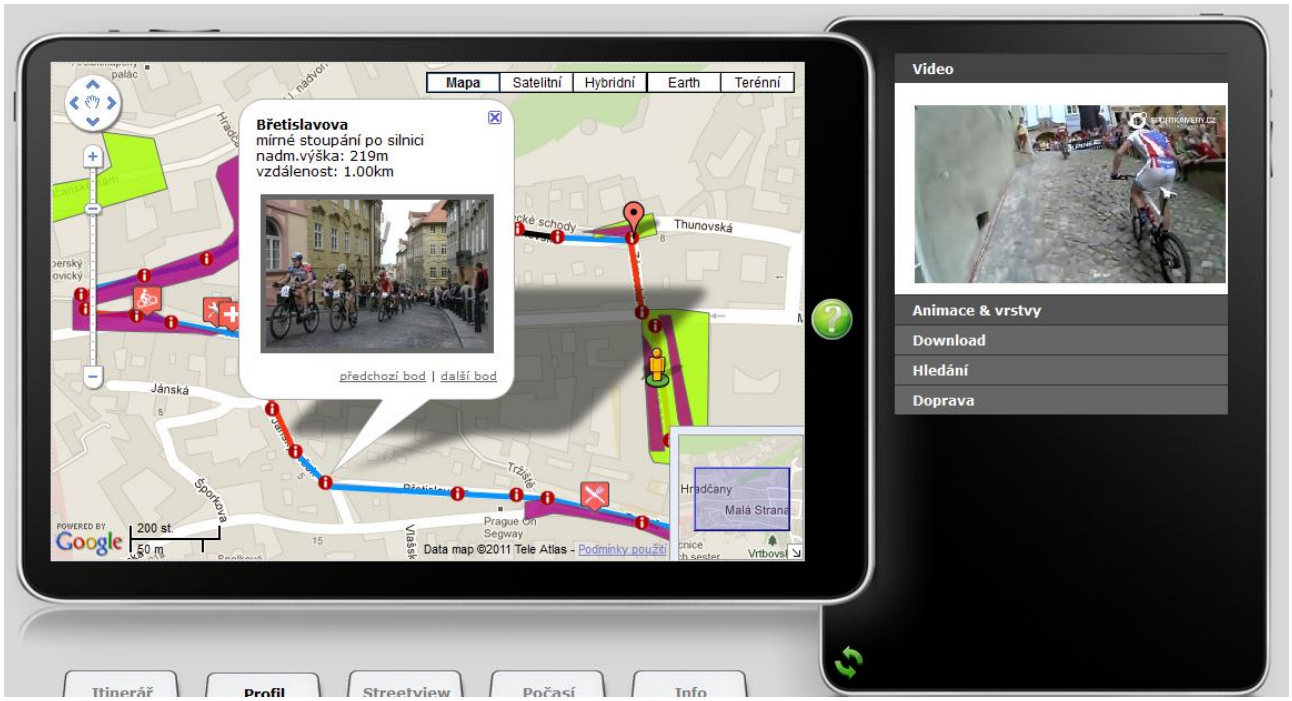

Fig. 8. Application “Pražské schody” Race

Interface

Web interface is divided into 3 main parts - the main map field, the primary tools menu on the right side of the map field and the other tools under the map field (Figure 8). There are also “Help” and “Page refresh” icons with adequate functions. After many disappointing attempts were for interactive profile used Flash technology, map field is based on Google Maps API - JavaScript version. The application was optimized and

correctly viewed in browsers: Firefox 3.6 and 4.0, Opera 10.60, Chrome 5.0. All photos are used with permission of the author Michal Červený.

Tools and functions

Map field use standard view of Google Maps, scale and pan tools are located in the top left corner, switcher between 5 layers (standard, satellite, satellite combined with the street network and descriptions, Google Earth, terrain) is in the top right corner. In the bottom left corner the graphic scale is located; on the opposite corner is small preview map, which can be minimized. Map movement is allowed by press the left mouse button while dragging the mouse or by the arrows in the top left corner. Zoom can be changed by the mouse wheel; function zoom by double click was disabled, because this process is assigned to searching by entry points. There is 34 “info-points” attached to each edge-point of the route and each of them includes the name, description, elevation, distance from the start, photography and links to the next or previous “info-point”. Click by mouse on the red “info-point” icon displays the appropriate information.

In the tool menu on the right side five tabs are located. The first one contains video captured from the perspective of bikers (camera was located on the biker´s helmet). In the second tab user can (de)activate layers (difficulty, type of surface, climb/descent, important points, critical points, spectator and parking sectors) and show its legend. There is also command to deactivate all layers at once. Very interesting is possibility to control animation by user (start / pause / resume / first-point/ last-point buttons) which automatically step-by-step displays information to each info-point. The third tab gives possibility to download the track in 22 different digital formats supported elevation data: KML, KMZ, PCX5, GPX Track, GPX Route, Garmin CRS, Garmin TCX, Garmin Logbook, OVL, Fugawi, KOMPASS Verlag, GeoRSS Track, Excel, OziExplorer, MagicMaps IKT, PathAway, Navigon RTE 5.x, Navigon RTE 6.x, Navigon Freshroute, TomTom ITN, Magellan, qpeGPS. In the fourth tab is standard search form, and the last one contains opportunity to find a connection with itinerary to the track for visitors.

The second tool menu under the map contains another five tabs. The first one is a detailed interactive itinerary connected with map (the map is centred on the selected item), in addition it allows searching and/or sorting records. The second tab, probably the most important one, contains an *interactive elevation profile* – particular points on the line profile corresponding with the location in the map, the map is centred when user pass through the profile-line. There is also available animation in three levels of speed; it shows the location in elevation profile and map continuously. The animations are allowed by <ele> and <time> elements in GPX file. Animation can be run at three speeds or manually moved. The third tab is about realistic look into the street allowed by StreetView technology. Localization of the projection point in the map is indicated by yellow-icon. The next two tabs show the current weather situation and basic information about the circuit. A complete list of features is available in Help.

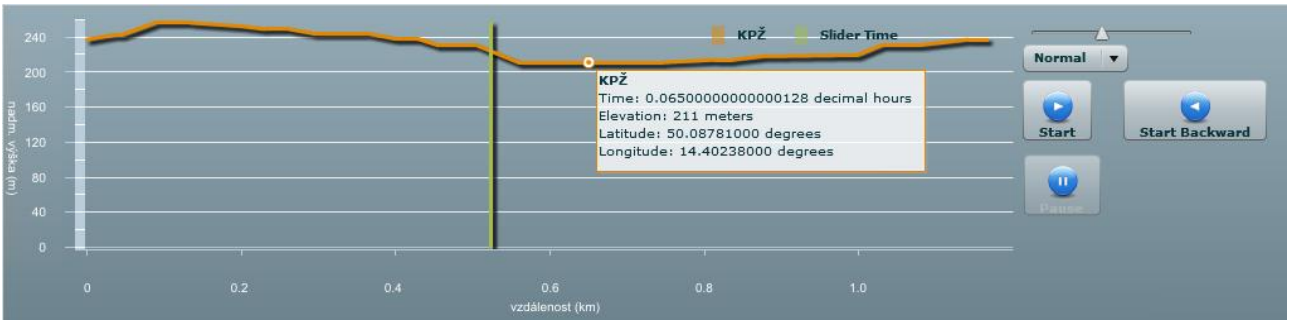

Fig. 9. Interactive elevation profile with animation of “Pražské schody” Race

Curent situation

The application has been tested, runs on the server and it is fully functional now. Due to a simple installation, is ready for immediate launch, regardless of its location, on other server and/or for any kind of sport. It is for free and fully independent on original author. There are number of really great similar applications, but mostly they are focused on concrete activity only. It provides great potential for widespread usage of similar

technologies in any sport activities (for organizers, racers and viewers as well). Particularly it is used for racers just now (web applications for performance's visualization), unfortunately in very limited form compared with wide opportunities. The behavior of the organizers is the biggest restriction, because they are conservative and often they don't want to include new technologies despite the advantages. First of all organizers must be opened for technologies of 21st century. When approach of organizers will turn to positive status, then we will meet GI technologies in every sport field everyday.

CONCLUSION

The paper shows an overview of elevation data with time aspect used by athletes for the training and competing activities. Because it takes a long time, from the first usage by professionals to spread to the public, is more relevant be focused only on professionals. Typical usage of 4D data for sport is so-called GPS tracking implemented in wide range of sports, both of individual and collective sports. There are specialized GPS tracking technologies and applications in sports such as cycling, orienteering, sailing, cross-country skiing or running as well. Field of professional sport and leisure-time activities provide a great potential for implementation both spatio-temporal and elevation data for analysis, visualization, evaluation and planning performance. Online web map application focused on mountain bike race exhibition "Pražské schody" was created. Together 22 formats of the race track are available; in addition to basic information about the route profile is supplemented with interactive animations, itineraries, videos, animations and other tools. It is obvious, that multi-spatial data together with modern geospatial technologies will play important role in field of sport in future as well. Geospatial technologies are becoming natural part of professional sport and bring big advantages for athletes and fans.

REFERENCES

Ahtinen, A., Isomursu, M., Huhtala, Y., Kaasinen, J., Salminen, J., Häkkilä, J. (2008) Tracking Outdoor Sports – User Experience Perspective. In: (ed.) E. Aarts et al.: Lecture Notes in Computer Science, Springer-Verlag Berlin Heidelberg, Volume 5355/2008, p 192-209,

Antikainen H., J. Rusanen, S. Vartiainen, M. Myllyaho, J. Karvonen, M. Oivo, J. Similä ja, K. Laine (2006) Location-based Services as a Tool for Developing Tourism in Marginal Regions. Finland, Nordia Geographical Publications 35:2, p 39-50. NGP Yearbook 2006.

Brown, G. (2007) GPS tracking for athletes? URL: <http://www.cyclingnews.com/news/gps-tracking-for-athletes> [cit. 2010/08/03]

Nétek, R. (2010) Implementace GIT pro organizaci závodu horských kol. Univerzita Palackého v Olomouci, Katedra geoinformatiky, Olomouc, 52 p.

Saupe, D. et al. (2007). Analysis and visualization of space-time variant parameters in endurance sports training. Proceedings of the 6th International Symposium on Computer Science in Sports (IACSS 2007).

Service Garmin Connect. URL: <http://connect.garmin.com/> [cit. 2010/08/04]

Veselý, O. (2008) Využití GIS při velké sportovní akci na příkladu MS v orientačním běhu 2008. Univerzita Palackého v Olomouci, Katedra geoinformatiky, Olomouc, p 22.

GPS eXchange Format - Wikipedia, the free encyclopedia URL: <http://en.wikipedia.org/wiki/GPS_eXchange_Format> [cit. 2011/10/26]

Yao, A., Uebersax, D., Gall, J., Van Gool, L. (2008) Tracking People in Broadcast Sports. In: (ed.) M. Goesele et al.: 32nd Annual Symposium of the German Association for Pattern Recognition. Darmstadt, Germany, p 151 – 161.

Zentai, L. (2005) LBS in orienteering sport. In: (ed.) Georg Gartner: Location based services & telecartography Symposium, Technische Universität, Wien, ISSN 1811 8380, p 249-252.