Visualization of cycling training

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ABSTRACT
In the era of big data, a flood of information obtained from pervasive computing devices is being available. Using latest data mining technologies, lots of information can also be processed. Since many of them do not present any significant meaning to users, information could be ranged in so-called significant classes, where these are selected according to their significance. This paper presents an analysis of data obtained during the cycling training sessions made by wearable sports tracker and later visualization of their most significant parameters. Every sports training activity should be presented in a simple, self-speaking and understandable figure, from which it is possible to deduce difficulty, strain, effort, power, conditions and pace of the visualized sports training session.

Keywords
visualization, cycling, cycling elements, .TCX

1. INTRODUCTION
A use of GPS sports trackers (trackers) for sports training purposes in cycling is increased every day. More and more athletes use trackers to measure, accompany and control data obtained during their trainings, as well as perform later analysis and online planning. Trackers are today embedded into sports-watches (e.g. Garmin Connect, Strava, Movescount, Endomondo, Sports tracker, etc.) or mobile devices offering an upload of datasets with tracked data to the mentioned sports tracker producer websites. Every cyclist collects his activity datasets in a so called calendar, showing daily training sessions.

Sport-watches and mobile devices provide a brand-new approach of training, not only for cycling, but also for running, swimming, canoeing, hiking, roller skating, skiing, fitness, and other sports. Some of the specialized trackers support additional functions, like summing the number of daily steps and predicting calories burnt (therefore measuring the daily consumption), analysing daily weight and measuring average sleep quality by measuring movement of the arm [5].

All those properties, which became accessible to every athlete, lead to huge and complex online trackers, offering lots of data. But these data should be correctly interpreted in order to became useful information for an athlete. In line with this, different applications for visualization in sports have been emerged. For instance, the more frequently used visualization tasks are described in [7], but these are especially suited for the team sports. The analysis of the cycling data is well described in [3], while the advanced data-mining approach in [6]. The cycling training sessions and its planning can be seen in [4].

This paper proposes visualization of cycling elements, where athlete's data obtained from an archive of the activity datasets are interpreted. Based on athlete's effort, specific figures are built, from which it is possible to obtain the most significant class information about the performed sports training activity.

The organization of the paper is as follows. In second chapter, basic elements of cycling training are described in details. Third chapter offers background and description of proposed visualization, while the fourth chapter deals with results. The paper ends with conclusions and outlines the directions for future work.

2. ELEMENTS OF CYCLING TRAINING AND VISUALIZATION BACKGROUND
In this paper, we are focused on visualization of cycling training datasets. Cycling datasets are, as mentioned in Chapter 1, created during a sports training session. Cycling trackers usually record properties from the most significant class consisting of:

- position,
- distance,
- duration,
- velocity,
- altitude,
- temperature,
- heart rate and

- power.

First six properties are recorded by tracker itself when wearing or carrying during the activity, while least two are provided by wearing accessories. Heart rate monitor and power meter crank are today's classic equipment for cyclists and are usually being used during the training. Data is commonly recorded every second into special .GPX or .TCX dataset. This means that many useful information (e.g., different graphs, coefficients, average values, fatigue prediction, feeling and performance evaluation) can be extracted from the activity datasets when interpolating data through time. Tracker analysers usually compete against each other to provide most data for athletes. Therefore, more and more information are accessible when updating the tracker (extracting data is still in research).

The results of analyser are forwarded to visualizer, whose main task is to interpret them. For specific athlete, data should be treated specifically, i.e., no generalization is desired. For correct interpreting, cyclist needs to collaborate with visualizer's personal dataset in order to properly range data for each athlete. One of the tasks of visualizer is teaching himself in the matter of improving athlete's performance. Therefore, regular updates of personal dataset are crucial before the visualization. Correctly updated visualizer should then correctly predict cyclist's efforts, no matter of age, experiences or personal habits. Following values are specified in personal dataset:

- daily norm of duration,
- daily norm of distance,
- daily norm of altitude,
- minimum and maximum velocity of an athlete,
- minimum and maximum hearth rate and
- Functional Threshold Power (FTP).

First three properties depend on the athlete's desire to what he wants to reach, while last three show his objective performance. FTP setting of power is a property, which describes athlete's ability to produce the specific amount of power in one hour.

For visualization figure, it is common to show athlete's daily feeling. Therefore, the cyclist should enter into personal dataset his/her feeling, or condition, on the day of training. Thus, three different feeling badges can be selected, i.e., good, bad and medium. Additionally, weather data can be downloaded from weather websites and added to visualization figure. In order to commence research and implementation of automatic visualizer, the prototype was manually schemed in the picture drawing studio (Fig. 1).

Fig. 1 presents the prototype of visualization designed in figure editing studio that serves as a basis for automatic visualization. It is worth to mention that cycling parameters shown in prototype are untrue and biased, but purpose can be clearly seen from it. Figure should be read by the color

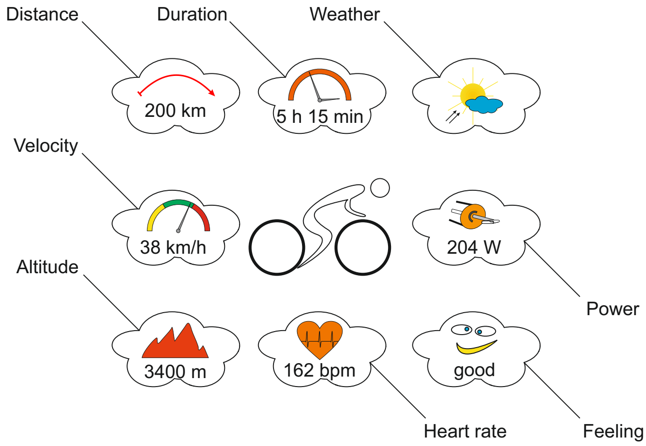

Figure 1: Visualization elements of the prototype.

of the cycling elements, as well as with an objective value. The curve representing the distance currently in bright red means that athlete almost reached the wished daily norm. The number below means total distance cycled and serves as supporting value of visualization. Speed meter represents velocity and is divided into three sections, presenting relaxation ride, tempo ride and competition ride. A deterministic value is added as well in order to prevent the misconception of reading the velocity meter slope. The same applies to duration, altitude, heart rate and power meter element. Colors are automatically chosen and adjusted to athlete's performance. They vary between bright yellow, as low-effort, and dark red, as high-effort (Fig. 3).

Fig. 2 presents the flow of events and data graphically. Starting by cycling, process continues to uploading and analysing of recorded data. Transformations from real to computer world are clearly seen as well as visualizing section with appropriate displaying results to cyclist.

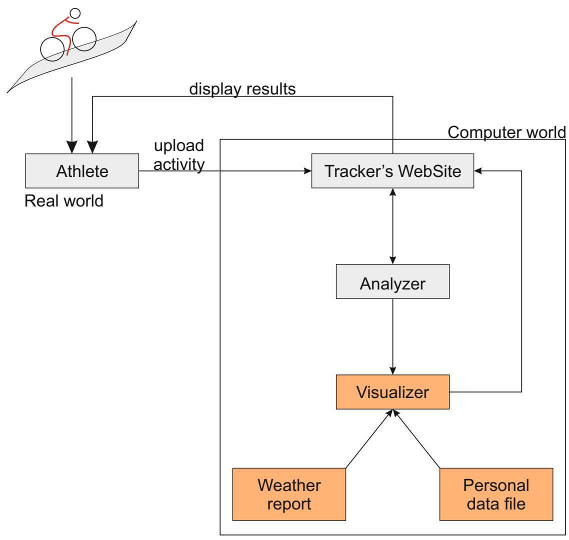

Figure 2: Visualization process.

As can be seen from Fig. 2, the visualization process is divided into three parts:

- completing the training session,
- uploading and processing data, as well as visualizing results,
- informing cyclist.

The first part is dedicated to the cyclist in real world. After completing his training, recorded data is transmitted to computer world in the second part. There, they are being processed, visualized and displayed on the website as a result. In third part cyclist can inform himself about the training's effort and therefore struggle even more next time.

3. CYCLING TRAINING ELEMENTS VISUALIZATION

The visualization process is performed using a software suite ImageMagick and Ruby programming language [2]. ImageMagick is the open source text-mode editing software for pictures, which excellently collaborates with the Ruby language. This combination of software was applied in our study because of high adaptability, simplicity and integration. Algorithm 1 presents the basic visualization process.

Algorithm 1 Visualization principle

1: Athlete uploads cycling activity dataset to tracker's website;
2: Analysis of uploaded dataset begins;
3: Analyser forwards extracted data to visualizer;
4: Visualizer reads data and retrieves personal dataset;
5: **if** Personal dataset should be updated **then**
6: Update personal dataset;
7: **end if**
8: Visualizer downloads actual weather report;
9: Visualizer interprets data to become information;
10: Visualizer generates a figure and forwards it to website;
11: Website presents the visualized figure of the training activity session;

Algorithm 1 presents the standard visualization process, taking into account both of the accessories (i.e., heart rate monitor and power-meter) by default. It should be noted, that the visualization process is adjusted, when cyclist does not use any of them and visualization figure is different than shown one (Fig. 1).

3.1 Visualization of distance, altitude, duration, heart rate and power

Let's say, that analysis part has been completed and extracted data are ready to be interpreted. Interpretation actually means comparing extracted data from tracker and values obtained from personal dataset. An example shows the comparison for the distance element:

$$INTERPRET\_DISTANCE = \frac{actual\_distance}{max\_distance}, \quad (1)$$

where $INTERPRET\_DISTANCE \in [0, 1]$.

After obtaining result $INTERPRET\_DISTANCE$, which lies in the interval [0,1] a color for the distance curve is selected. Ten colors are available for ranging the intensity of cycling elements. If the result of distance is $INTERPRET\_DISTANCE = 0.45$, then the corresponding color in interval $[0.4, 0.5]$ will be selected, i.e., bright orange as can be seen from Fig. 3.

Color table
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0

Figure 3: Color table.

Interpretation of altitude and duration is performed on the very similar way, while interpretation of heart rate and power is a bit more sophisticated. It should be mentioned, that it would be silly to interpret, for instance heart rate $HR = 56$ bpm on the training, because this can mean that cyclist did not actually move. To prevent appearance of such errors, we suggest to add besides the set of maximum values also the set of minimum values. Consequently, actual data should be spread between minimum and maximum values, e.g. heart rate should be drawn from interval $HR \in [120, 180]$ bpm. Accordingly, Eq. (1) transforms into Eq. (2):

$$INTERPRET\_POWER = \frac{actual\_power - min\_power}{max\_power - min\_power}, \quad (2)$$

where $INTERPRET\_POWER \in [0, 1]$. If the $actual\_power$ is lower than min_power, the min_power is taken into account and $actual\_power$ is disregarded.

As a result, listed elements are colored in the appropriate color and finally added (imported) into the primary figure.

3.2 Visualization of velocity

As seen in prototypical Fig. 1, velocity, weather and feeling are not presented by color, as other elements. Therefore, a different approach was studied for those elements. One of the most self-explaining principles of presenting velocity in general is using a simple indicator with three background arc colors. In fact, reading the slope of the indicator is the easiest way to determine velocity and that is the reason for employing it in our application. Background arc colors can be pre-drawn and pre-imported into file to make whole process easier, but indicator has to be programmed and processed at the moment of visualization, indeed.

The scheme of velocity indicator consists of three mutually connected points. Connections create so-called polygon, which has to be properly positioned and rotated to express wanted velocity. Position can be fixed, due to fixed color arc in primary figure, but rotation is a matter of two read values, written in personal dataset - expected minimum and maximum value. Those extend the velocity range, e.g. 25 km/h as the lowest velocity and 45 km/h as the highest velocity. As stated, those conditionals call for the automatized calculation of indicator's tip position. In Ruby, programming of indicator and its movement was executed by simple mathematical equation, consisting of trigonometrical functions. First, the slope in degrees is calculated using following equation:

$$SLOPE =$$

$$\left(actual\_velocity - \frac{min\_velocity + max\_velocity}{2}\right) \cdot 9^{\circ}, \tag{3}$$

where *actual_velocity* is parsed from .GPX, or .TCX file and *min_velocity* and *max_velocity* read from personal dataset. 9° is used as section interval, meaning that 1 km/h presents 9° in inaugural form and is updated if updating personal dataset.

After calculating the needed slope, the tip's position is being calculated using trigonometrical functions in following equations:

$$x\_position = \sin(SLOPE) \cdot 202.5, \tag{4}$$

$$y\_position = \cos(SLOPE) \cdot 202.5, \tag{5}$$

where 202.5 presents the length of the indicator from the center of color arc to the tip end in pixels (Fig. 4).

Figure 4: Velocity indication.

3.3 Visualization of weather and feeling

Visualization of weather is divided into two parts. First part presents the general weather conditions - sunny, rainy, cloudy weather, while the second part deals with the magnitude and direction of wind. Data is downloaded and parsed from the aviation weather's site, called Ogimet [1], which offers aviation weather reports, called METAR (Meteorological Aviation Report). The METAR is a simple, text-based weather report, from which weather conditions can be determined. For us, it is particularly important to be aware of clouds and possible wind blowing, therefore only little of report is parsed. To get proper weather report from website it is also necessary to locate closest weather station to activity position, what is still under research.

Meanwhile, weather condition figures are drawn in advance, so only compositing of them to the right place is necessary to expose the weather conditions. If sunny weather is reported, only sun is exposed and opposingly, cloudy weather is seen from figure, if clouds are described in METAR (Fig. 5):

Figure 5: Weather conditions.

Fig. 5 shows basic weather conditions, which serve as the first part in describing weather. Describing the wind, or second part, is more sophisticated. First, the direction and magnitude are gathered from weather report. Next, the length of the wind flag is initialized. Position of the wind flag tip and its end are calculated to continue the calculation process and finally the line between them is outlined. To certainly specify wind direction, the wind flag's ending tips are drawn (Fig. 6). The calculus part consists of many trigonometrical function and is very long, therefore we excluded it from paper.

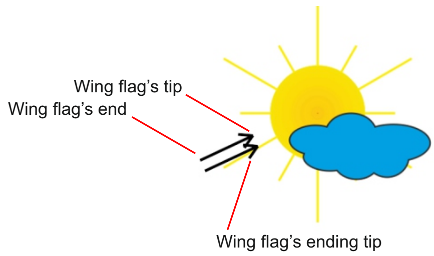

Figure 6: Describing wind.

Three different magnitudes of wind are applicable in our work:

- wind velocity from 0 km/h to 5 km/h: no wind flag,
- wind velocity from 5 km/h to 15 km/h: one wind flag,
- wind velocity from 15 km/h and above: two wind flags.

Visualizing feeling bases on the athlete's manual input. Three different feelings are included in program, which vary from bad, medium and good (Fig. 7). As standardized, all three figures are drawn into advance and imported into primary figure on the appropriate position after cyclist's decision.

4. RESULTS

Results of cycling's automatized visualizing are presented graphically for three different training stages:

- after-season relaxation,

Figure 7: Describing feeling.

- mileage training and
- competition.

Result are constructed on a single cyclist, who had fulfiled his personal dataset based on his experiences and uploaded three different .TCX files to website. They have all been analysed and sent to our visualizer. It then generated three figures, which suppose to be shown in the athlete's calendar of activities.

4.1 After-season relaxation

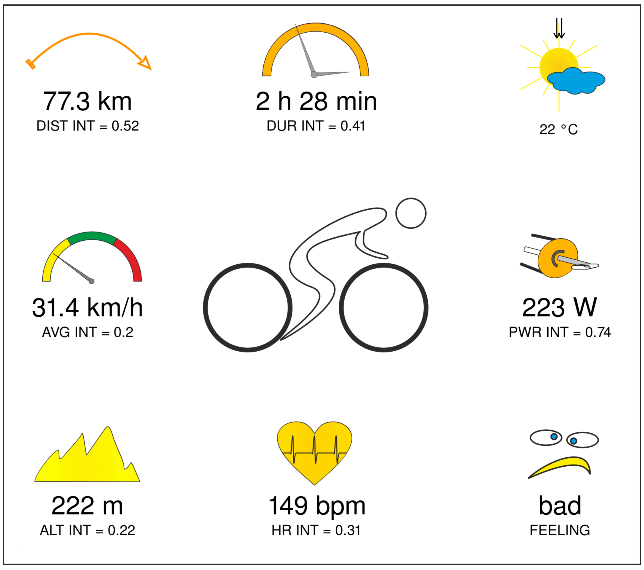

Figure 8: After-season relaxation.

Fig. 8 presents after-season relaxation training session. Cyclist did quite short training, what is seen from distance and duration. Its colors are orange, meaning that athlete only did half of his maximum. Cyclist did rode slowly, with low pace, what can be also seen from his pulse. His power was quite good, considering the flat ride (low altitude) and bad feeling. Cyclist probably did a short, regenerative training in order to raise his feeling and performance for next day's training, which will probably be much more difficult.

4.2 Mileage training

Mileage training is a long, distant training, seen from distance and duration elements on Fig. 9. Cyclist did train more than 100 km more than in first result. Cyclist did much altitude, due to red colored altitude indication. The weather on that way was cloudy, without wind. His feeling was medium and his heart rate like expected - in the

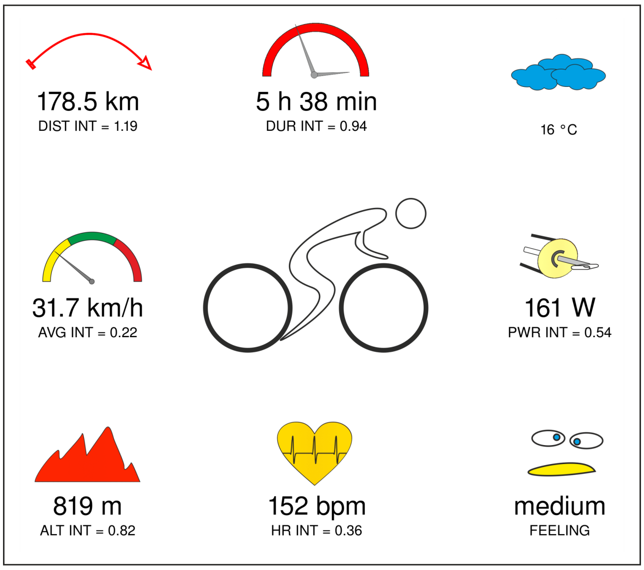

Figure 9: Mileage training.

strong yellow section to save his energy for the whole ride. The answer on the question, which asks why did the cyclist reach higher power in after-season relaxation than in mileage training is a bit complex. First, the power shown on the visualization figure is not average, but normalized (NP). NP is a correction of average power, due to rapid changes in training intensity and due to curvilinearly physiological responses [8]. In the first result, athlete probably did some intervals (escalating intensity) during the training to stretch his legs, which are rapid changes in intensity, and therefore improved his NP shown in the figure. Practically, rapid intervals on the training make NP higher. Oppose to first result, at this long ride, athlete did save with his energy and did no short intervals and no intensifying is observed from Fig. 9.

4.3 Competition

Competition visualization is as at first seen very relaxational (Fig. 10). Athlete did only little more than twenty kilometres, getting the distance curve barely noticed. His ride last for only half an hour, identifying yellow color from duration element. But otherwise, athlete had struggled at most by other three results - his average heart rate was 182 bpm, normalized power 294 watts and velocity 43.2 km/h. They are all in the red section, meaning that athlete surely competed at the time trial. He chose flat course, having only few altitude, therefore getting his velocity very high. His feeling was bad, at strong south-west wind and some clouds, meaning that cyclist could drive even faster.

5. CONCLUSION

In this paper, we presented a novel approach for visualizing most important cycling data. Accordingly, a visualizer in editing studio ImageMagick was implemented and controlled by Ruby programming language. We practically executed our approach and showed, that it is possible to automatically generate expected figures. Results of the performed work are, due to rapid visualizing (only five seconds per figure), excellent. The precision of process is valuable and resolution of figures is acceptable.

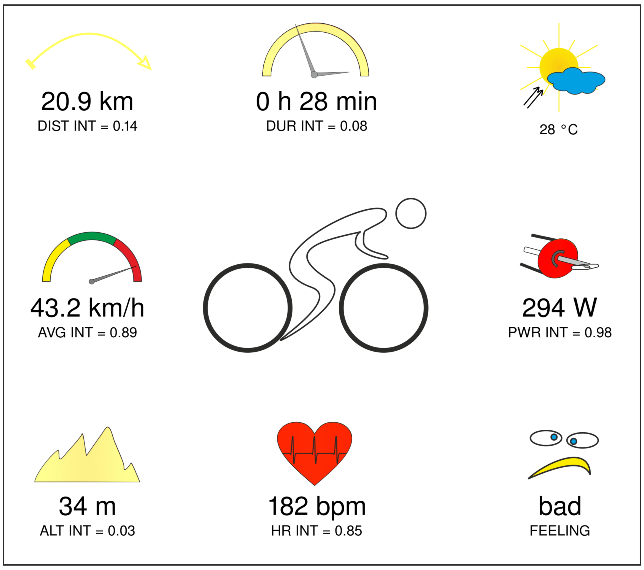

Figure 10: Competition.

However, some cues remain for the improving the paper:

- some graphical weather elements should be added, e.g. symbol for rain, snow and fog,
- standardized visualization scheme should be transformed into an adjusted one, if athlete does not own a heart rate monitor, or power meter during the training,
- the default feeling should be set to good by default and changed only after athlete's intervention,
- drawn symbols, which represent altitude, heart rate, weather symbols, power meter and feeling should be completely created in the ImageMagick studio (currently they are drawn in advance and imported into primary figure),
- automatic parse for weather should be implemented,
- sports, like running, swimming and roller-blading should be added into visualization with their elements (Fig. 11) and
- analyser should be implemented to read data from trackers.

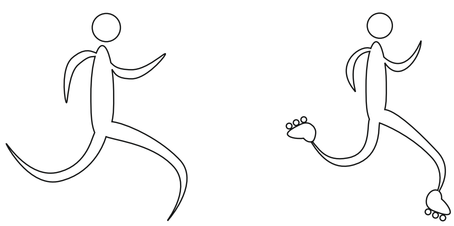

Figure 11: Running and roller-blading.

The evaluation of cycling data visualization was satisfactory implemented. It is worth to continue research in this way, since it may help to many cyclists.

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