

User-friendly Smartphone App for Heart Rate Monitoring in Sports Endurance Activities

Improving Training Control by Combining New Technologies of ANT+ and Android

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Abstract: In endurance sports training, heart rate represents a useful proportional measure for the current physical effort in a workout. Accordingly, during such exercises, it is advantageous to get monitoring information about the actual heart frequency for having an instrument of controlling the demand level of an activity. Today, the market offers a broad variety of sports computers, which allow a tracking and display of heart rate, but their convenience and appropriateness appear rather limited in terms of an efficient use in daily training. In particular, major restrictions are numerical displays of the in-time measures with tiny letters or an unfiltered print-out of spurious values, since the recording is not always precise, but sometimes disturbed from various reasons. Fortunately, upcoming new technologies like programmable smartphone devices and ANT+ communication standard for sports sensors allow developing new and optimized applications and systems also for sports purposes. In the work here, a convenient heart rate monitor was developed that aims at high user-friendliness in combination with elaborated signal-conditioning for preventing any spurious and misleading displays. Few simple button presses put the sportsman into the position of performing efficient activities within the desired endurance training range. As result, a system is described that is feasible for easy-to-use and efficient sports monitoring, especially during daily workouts.

1 INTRODUCTION

During physical training it is important to know the actual blood oxygen supply level for categorizing such activities into the effects of regeneration, aerobic and anaerobic training. This is required, because then only dedicate training units will lead in a controlled and predictable manner to the desired training goals (Kindermann et al., 1979), for instance building up speed, over-all endurance or muscular strength. In practical sports medicine, blood is extracted from the training sports person and the analysis of its lactate concentration yields the state of the oxygen supply, but this method obviously is too complicate and too expensive for being continuously used as monitoring instrument in daily training units.

Fortunately, an alternative measure, which is applicable at much better convenience, has been identified since long time: monitoring of the heart rate (HR) allows a replacement of the direct measure

of the blood oxygen level by a proportional value (Arts and Kuipers, 1994).

More precisely, as established measure the percentage value of the actual heart rate in relation to the maximal possible heart rate ($MHR = \text{maximum heart frequency}$, also called HR_{\max}) of the individual sports person is used. Consequently, this kind of monitoring approach is commonly applied for field investigations in medical science (Hoppeler et al., 1985) and even in sports research (Tabata et al., 1996). Figure 1 provides a sketch of the main sports activity levels as these are mapped to different bands of heart frequency.

For beginners in sports – especially, older ones – it is established practice that they first build up their base performance in range RECOM and then after sufficient advance continue within BE_1 , since exceeding these levels could even be hazardous for such untrained people. In general, efficient sports training requires a certain, well-known mixture of these activities levels in Figure 1. Else there won't be any power advance or even physical deterioration

after a certain point despite continued high training efforts.

As sample reference, Figure 1 exposes also some typical ranges for different running activities in the right column, while the left column in the table applies to human sports activities in general.

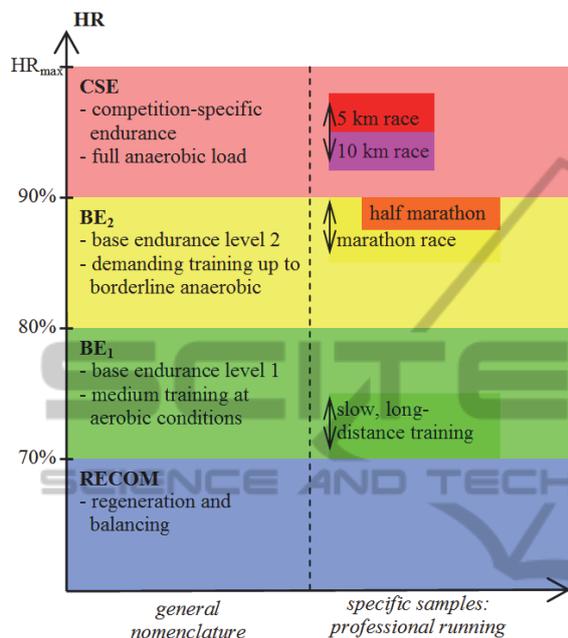


Figure 1: Activity categories as function of HR_{max} (the maximal individual heart frequency).

Electronic consumer market offers today a big variety of devices for HR monitoring (Figure 2). This ranges from rather simple and cheap watches to elaborated sports computers. All of them are tiny, wearable devices, but their ergonomic use in terms of user interfacing (UI) appears rather low, when considering fundamental knowledge and experience for the research field of human computer interaction (HCI). Usually the actual heart rate is printed in letters of limited size and often with limited contrast on B+W displays. This invokes two fundamental problems, since this kind of output is

- readable at a low speed only
- must be categorized by the training persons themselves (refer to Figure 1)

Certainly, people usually claim that they can easily remember the desired limits for their training in terms of lower and upper heart rate. In training practice, after longer time of demanding activities, the true experience is quite different: even the comparison of the simple numbers will get really slow and causes considerable extra efforts, after, for instance, attending several hours in a distance run.

Another effect is, that the measuring results from the heart sensor are sometimes disturbed for spurious reasons, and displayed totally unfiltered by the sports watches. In general, systematic errors in the sensor information have been reported recently for such sports devices (Weghorn, 2013).

The actual trend of the HR – in particular the question, whether the heart is getting slowly too high or too low – is relevant for efficiently controlling an on-going workout. Despite this interrelation, the HR trend has to be traced manually by the sports user, while observing HR number display of the sports computer and calculating then the slope “by hand”.



Figure 2: Typical sports computers and watches, which can perform heart rate monitoring as main feature or in addition to other functionalities.

As positive UI feature, there are also some modern concepts available; in particular, some sports computers allow to program the limits for monitoring the lower and upper HR during the workouts, and there is even a haptic warning signal generated, since the device is vibrating, if one of these limits is exceeded.

In daily use, it often turns out that this feature is worthless, because the unfiltered HR measures continuously produce such warning signals. Furthermore, the warning signal in the sports watch is often identical for the events of too low and too high values. This makes it impossible to interpret the haptic notification correctly without further reading a message that is displayed in even smaller letters, since the corresponding printout carries more information and requires more characters that have to map on the tiny screen.

From fundamental HCI research it can be derived, that information perception in computerized displays can be accelerated by different principles:

- Using colour as information indicator (Brown, 1999)
- Using analogue graphics instead of values that are in printed in letters

As standard knowledge from the use of technical systems, it is commonly suggested that an analogue tachometer is read approx. three times faster than digitally displayed ones. Although investigations from the modern application field of automotive do not proof this number as precise value (Kiefer and Angell, 1993), they do support the general theory that analogue displays are perceived at least as fast, by tendency even faster than digital ones.

As complementing UI aspect, the benefit of colouring texts is well know and has been investigated thoroughly during the time, when coloured computer displays came affordable and were widely commercialized. Systematic research has shown that the use of colours increases the finding speed for a certain passage on a screen (Carter 1982). The best colouring scheme was found to use colours that are as distinct as possible for enabling the fastest perception of different information contents (Robertson, 1988).

For the user's convenience, the categorization and the detection of out-of-band-trends could be easily performed by the sports computers and data filtering could prevent the display of erroneous or misleading outputs. The calculated results and trends, and especially the commands, whether the training should be more challenging or slower for mapping the desired working range, can be indicated to the user in a more easily readable manner than just exposing the plain digits of the current heart rate. Graphical symbols and/or colouring can be used for this purpose.

In the following sections, the considerations and deductions are discussed that led to the design and construction of an appropriate heart rate monitor that is intended for sports and health exercises. First scope was an improved UI that meets standards according to the established knowledge from the field of HCI. Second focus was a general improvement of signal processing, which is described in the next section, as it depicts the base for the whole UI concept.

A relevant part of the improvement is also that the person, who uses this device, is not required to know all the numbers and relations of sports training categories, but simple button presses inside the application allow defining the proper and desired demand level of the workout. Accordingly, the system is even more valuable for beginners and in sports endurance trainings.

2 SIGNAL CONDITIONING OF HEART RATE DATA

2.1 Low-pass Filtering of Input Stream

For the detection of heart activities, the use of special chest straps has been established and commercialized. Such products work really reliable also for long time of continuous use. Commonly, the signals are recorded from two skin electrodes across the lower chest, and are then processed by a tiny hardware module on the belt that transmits the result via RF to any data processing sink.

In the experiments here, a comfort chest strap of the manufacturer Garmin Ltd. was used, its RF transmission is composed in accordance to the ANT+ standard (Dynastream, 2011) that is discussed in the section about technical aspects of this work.

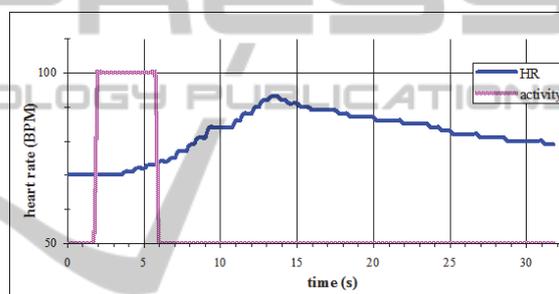


Figure 3: Experiment on the slope of the heart rate. After slight warming up, three pull-ups were completed while holding breath during the plotted activity window (rectangular curve). The heart rate responds by a gradual increase with delay, while the relaxation phase follows at an even slower remission speed.

For the fundamental concept of the signal processing of the raw input data, it is relevant that the initial sensing produces four measures per second, a sampling rate that is typical for such chest straps. The observation is that sometime these HR measures appear spuriously distorted, the reasons have not scientifically been investigated yet, but are suspected being manifold, e.g. the electrode contacts are not always accurate due to body movements, electronic problems, and RF disturbances.

The dedicate reasons may vary, of importance is mainly, how further processing can overcome such effects of falsified input data. As signal processing standard, statistics yields the answer by averaging consecutive measures as it stands for filtering the effect of such unavoidable and unpredictable short-term disturbances.

The properties of such a low-pass filter have to be aligned to the physiological behaviour of the

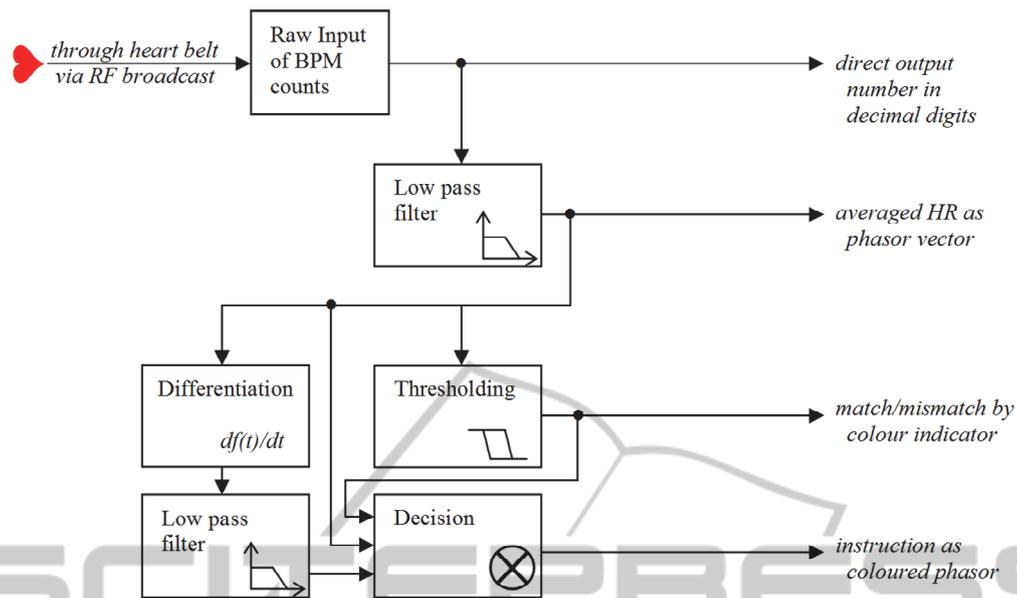


Figure 4: Generation and consumption model of the direct and deduced HR measures.

human body in general, since averaging in terms of any low-pass filtering will suppress the slope of the output signal and, therefore, may lead to wrong macroscopic measures, which would automatically consequence wrong instructions for any on-going training activities.

Medical research is much older than mobile computer technology, and hence, base investigations about the slope of the HR under certain influencing conditions can be found already from the last century (Josenhans, 1967). In this extreme, but indicative experiment, stopping breath followed by physical effort showed already that the body reaction in terms of increasing heart beat rate after sudden load events may be delayed in the order of seconds.

This easily can also be tested with modern computer technology like in the practical experiment in Figure 3 (an engineering version of the HR monitor was used in this test). From both sources, it can be deduced that averaging HR samples within a range of few seconds will still yield sufficient results with adequate slope. Hence, a time slot of 2.5 secs, which stands for an averaging frame of ten incoming sensor measures, is applied in the software construction here. A sliding time-window is used, so the avering stage yields also an output rate of 4 values per second, which is synchronized to the input data stream.

2.2 Feature Extraction

Figure 4 shows the processing chain of the direct

sensing results as it is used as tier for four output information streams, which are to be exposed to the sports user (the corresponding particular UI methods are discussed in the next section in detail).

In accordance to the different output indicators, the HR has to be compared to thresholds. For instance, if a 60-years old person wants to perform exercises at the effort level of BE_1 , the heart rate should typically remain within the band from 119 to 136 beats per second. This mapping yields one important control information for the workout.

Another relevant information is the current trend of the on-going activity. Is there a trend that the exercises are running out of the desired band? This can be detected by differentiating the averaged HR curve. The derived slope indicates, whether the pulse is getting too low or too high.

In practice, there will continuously be a slope that is non-zero, but the relevant matter is, whether the value is truly running out of band. With human as part of a control loop, correction indicators have to be applied carefully, else over-reaction easily may produce an undesired oscillation in the system. In general it is difficult to set a precise level of physical effort, although the body control can improve with growing experience.

Hence, for out-of-band trends it makes sense to have two stages of indication: first level is just exposing the current situation (applied when there is only slight de-/increase) without any further instruction. The second is to more clearly indicate the wrong eveloment and combine it with a



Figure 5: Collection of photographs of output screens for different use situations. As seen here, the UI is constructed in a self-explaining way. For testing of the output colour scheme, the MHR was set to a non-physiological value of 100 bpm for the right two test images.

particular instruction for the activity like asking to slow down or speed up.

For the technically and medically interested user – of course – the unfiltered heart rate may also be of relevance. In summary, this analysis yields four output information streams for a display to the user: the raw data sequence and three filtered and processed derivatives of it.

3 OPTIMIZATION OF THE USER INTERFACE

3.1 Visualization of Outputs

The primary goal of the user interface is to provide an information display that is as clear and as quick and effortless readable as possible. This display shall expose the situation and – if required – provide instructions of how to behave for staying within or – in case there is a mismatch already – of getting back to the desired training stress level.

As known from many other applications like, e.g. car driving and weather stations, an analogue tachometer is used as main display for the actual heart rate (Figure 5). The phase vector inside the tachometer circle is controlled by the averaged HR, the corresponding indexing hand is drawn intentionally big for achieving high and quick readability.

The information, which is to be controlled most

often for an efficient workout, is indicated by colour: Bright green exposes that the heart rate is within the desired stress level band. If the HR drops too much, this colour turns to blue, if it is getting too high, it turns to red. In this colour indicator, the rule of readability was infringed intentionally: there are not only the three, very distinct colours of blue, green and red in the scheme, but the transition between these colour states is smoothed.



Figure 6: Colour transition scheme for indicating the match or a gradual mismatch of the heart rate.

Like explained before, the human is a critical factor in the control loop, because over-reaction could arise easily by wrong reading or interpretation of displays: it doesn't make sense to suddenly turn the display indicator for the non-mapping heart rate from bright green to bright red, if the range is just missed by one single or a few counts, because this certainly would provoke too strong corrections.

As result, the slope of this indicator is smoothed by a gradual transition of colours. This scheme was experimented manually with the display appearance of the used smartphone, since it turned out that a straight calculation of ramping up and down of the RGB base colours looked inconvenient and not

sufficiently sleek; the best scheme resulted in an asymmetric number of transition steps (Figure 6).

The raw data value, as it is received unfiltered from the chest strap sensor, is displayed in big letters and at high contrast. If the sports user really wants to know this information from time to time, it is read easily also from a distance. This appears useful, for instance, when any type of ergometer or treadmill is used, and the device has not to be close to the body, but can be placed in convenient viewing distance and direction. In such cases it even can be avoided to turn the head from the normal workout position for perceiving the information like it is required with built-in displays of such sports apparatuses, which are often mounted below chest height.

Just for technical information, a blinking heart symbol indicates that the RF link to the heart beat sensor is working correctly (located in Figure 5 below the tachometer centre).

If the system detects that the HR is going to exceed the defined limits, another UI element is activated as indicator. A phasor is tilted upwards or downwards, which stands for the instruction to speed up or slow down with the on-going effort respectively (effect is visible in the right two photographs in Figure 5). Depending on the strength of the wrong trend, the phasor is tinted more or less in red tones.

Table 1 summarizes the reading hierarchy, which stands in accordance to the use frequency of the information puzzle pieces for dedicatedly controlling a workout.

Table 1: Use hierarchy of display information.

<i>Indicator for</i>	<i>UI mode</i>	<i>Frequency of use</i>	<i>Perception time</i>
HR inside range	Colour/analogue	~ 1 / min	≪ 1 sec
HR value	Phasor/analogue	> 1 / min	~ 1 sec
Instruction	Coloured phasor	> 1 / min	~ 1 sec
Precise HR	Number print	rare	> 1 sec

3.2 Efficient Input Controls

Totally new in this construction is a convenient selection of input controls and it is thus the third big improvement in comparison to commercial heart rate monitors (Figure 2). As listed in Figure 7, a set of quick buttons is available on top UI screen, through which the user can set the monitoring level according to Figure 1. For this, it is required that the MHR is configured once in the application (accessible through standard settings menu like is implemented in all smartphone apps).

This MHR parameter is critical, best is, if it is determined under supervision of an experienced doctor. There are many, different formulas in various sports discussions panels found on the Internet as also in various research papers. The two described main methods, which yield slightly different results, are based on the age of the person. No valid scientific foundation for these calculation rules was found in literature, and hence the sports user is not offered in the heart monitor to enter the age, since the calculation of a wrong MHR could be risky or at least lead to inefficient training ranges.

The quick buttons for the effort level simplify the control considerably. According to the invoked function behind, it is not required, that a sports user does know all the relations between training goals and heart rates, and the system also releases the sports user from continuously validating in his head, whether the HR maps like desired. Besides the standard effort levels, there is also a button for activating a more dedicate trainings plan. This initiates a well defined sequence of varying effort levels; for instance, it may be programmed that the sports user first works ten minutes in RECOM, then 10 minutes in BE1, then 10 minutes in BE2 and before terminating the workout, again 5 minutes in BE1. Of course, such a plan has to be entered with all its stages into the system, but this method is required for advanced sports training anyway.

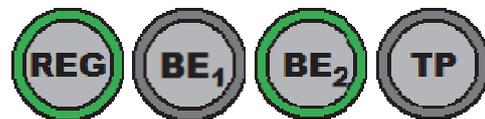


Figure 7: Quick buttons design for setting the desired training effort level – collection of active and in-active screen buttons (refer to use cases in Figure 5).

There is one button for activating the RF link to the heart belt, which is of technical function. If the air link is active, a beating heart symbol inside the HR tachometer indicates the working connection (Figure 5).

There are further buttons, which can be relevant for the trainings: one for starting, and a second for pausing and stopping a workout (low part of the UI screens in Figure 5). The starting button stands for a recording of the heart rate samples. It has got a double function as it also starts a programmed training sequence as described before, if this mode is activated.

At the moment, the recording is stored to a XML-coded file on the multi-media card of the phone. From there, it can be directly downloaded

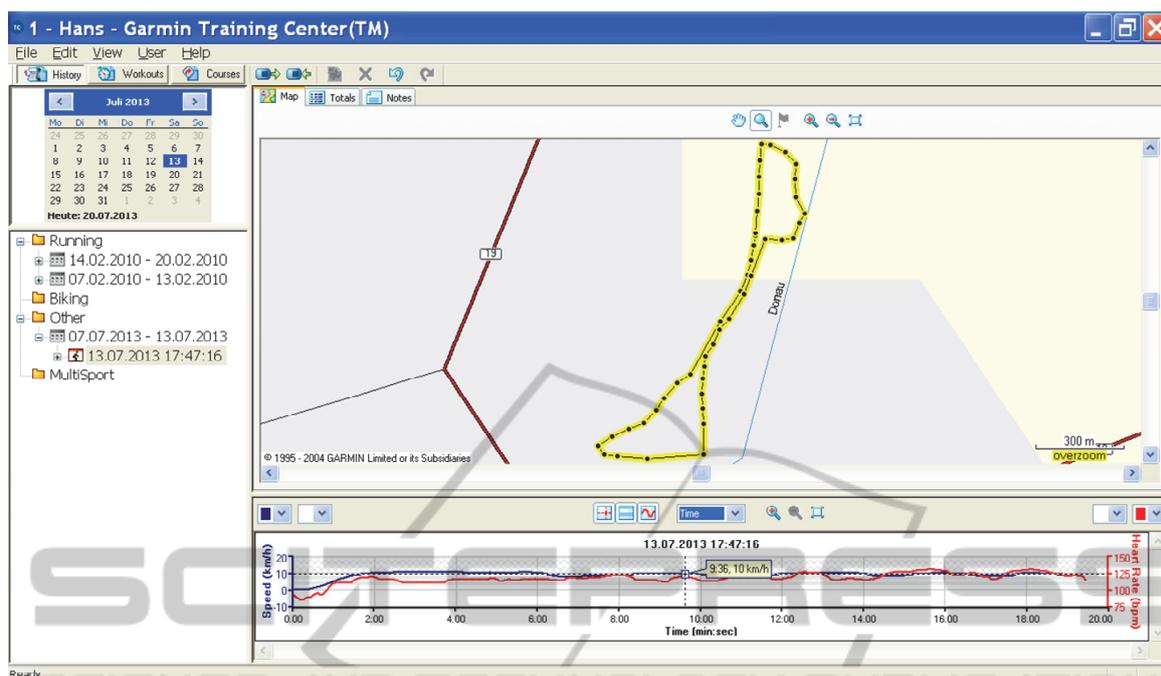


Figure 8: The XML recording of the HR monitor can be imported through a USB cable from the smartphone by a few mouse clicks directly into any sports analysis software on a personal computer (the “Garmin Ltd. Training Center” was used here). In this experiment, a 3 kms inline skating lap was completed, main output is the analysis oh HR plots (red curve in the lowest sub-window). As feature that complements the HR tracking in outdoor sports activities, GPS positions were recorded during the test also: this was working with sufficient quality despite the fact, that the HR device was carried inside a rucksack on the back of the sports person.

into any compatible sports evaluation software, which is running on a personal computer (e. g. the Garmin training center, or similar others). On the personal computer, the records can then be analyzed and archived for a long-term planning and trace of workout activities. If the GPS signal is available, the heart rate records are also tagged with GPS position information (result of a skating test lap visible in Figure 8). Since the XML format is not space saving, the GPS tagging is performed at a low rate (4 samples per minute) to keep the total files size within reasonable limits.

All control buttons are designed as “self-expressive”, which is achieved by using standard nomenclature and commonly used standard symbols.

4 TECHNICAL ASPECTS AND REALIZATION

Similar to the evolvement of mobile phones in their first generations, sports watches and computers are closed technical systems, regardless whether they are simple or elaborated. Neither their functionality, nor their software can be modified. For smartphones,

it is meanwhile well established that other people than just the constructors of these devices can bring own software applications on these units or can even extend hardware through standard interfaces. For the experiments here a smartphone with the “open” operating system Android was chosen (Collins et al., 2011), since there is lots of support and introductory material available in terms of books and on the Internet in documentation and developers panels.

Industry for sports computers has agreed several years ago on a new RF communication standard, which enables the interoperability of devices from different vendors. In the past, sports device constructors used their proprietary air link solutions, nowadays the so-called ANT+ standard (Dynastream, 2011) stands for an efficient data transfer from typical sensors like heart belts and tread or speed sensors for running and cycling. Like Bluetooth and WLAN, ANT+ uses the ISM frequency band, but at much lower energy consumption, which makes it possible that a heart frequency belt can run several days from the energy of one single lithium battery cell.

Since the corresponding working consortium for ANT+ is interested in spreading the concept, it

claims that there is a long list of smartphones, which do supply this communication link as well. In the end, the number of phones with built-in ANT+ interface certainly is growing, but nevertheless, it is not really broadly available, if all the available smartphones products are considered.



Figure 9: Upper arm pocket bag as it is part in the delivery package of the outdoor smartphone. This wearing solution does appear neither comfortable nor useful for any kind of sports activities.

At the time, when the investigations in this research were started, there were few and expensive ANT+ phones only. In this project, a Sony Xperia Active was selected as target device, it has got an older version of the Android operating system, but it was constructed especially for outdoor and sports use and it comes with a special pocket for wearing it at the forearm or upper arm during such activities (Fig. 8). There is good software support for developers from the phone manufacturer, but the ANT+ application software technology is complicated anyway, and it is proprietary.

With newer versions of smartphone operating systems, there may be a built-in standard software interfacing to ANT+. This concept theoretically will allow transferring applications, like the one in this project, more easily to devices of other brands. A possible greater target market for the heart rate monitor is moreover supported, because meanwhile there are heart frequency belts commercially available, which interface through Bluetooth instead of ANT+. Bluetooth certainly maps almost all new smartphones, but some doubts arise, whether these belts can be as power-saving and will have by that appropriate operational times.

Since the research question in this work is not of commercial interest, the development will continue also together with other related investigations on

sports sensors on this given hardware platform, despite the fact that the hardware/software approach can be considered already as overtaken by new technology generations on the market. On the other hand, the used phone still is sold on the market and advertised by its vendor as modern outdoor device.

5 APPLICATION SCENARIOS

Since the heart rate monitor is a versatile tool and not specific to any particular kind of sports, it can be used broadly. Especially, endurance exercises and training – and by that building up general physical fitness in sports or health – is the best field for its application. The smartphone can be mounted on a bicycle or on any type of sports machine in a way that it is easily visible by the user without unnatural movements of the head. Although training utilities like, e. g., treadmills and cycloergometers usually have built-in heart rate monitoring as well, these devices do often not easily or even do not at all work with custom heart frequency belts. At least, there is a procedure for registering an individual one and – furthermore – there may remain hygienic concerns when sharing such a skin touching belt with other people. After the workout it is often not possible to get access to the records of the training inside the computer of the sports apparatus.

Hence, using an own heart rate monitor also for such gymnastic machines provides in total several advantages, namely the opportunity for a natural and comfortable use during the workout, hygienic advantages and the possibility for easily preserving the records of the workout for later analysis and planning.

6 DISCUSSION OF CONCEPTS AND THEIR CONSTRAINTS

From well-known fundamentals of HCI research, the described approach of constructing a user-friendly heart rate monitor arises partially as straight-forward design. Of course, certain detail questions (e. g. transition scheme for colour indicators, averaging duration of raw data input) had to be researched in literature and complemented by own practical experiments.

Although the system appears applicable for its intended purpose, the usability has to be proven yet by scientific methods. This is planned during the upcoming summer season mainly in outdoor

activities. The system has got also some limitations, which arise from its technical construction. For instance – due to the RF communication inside the ISM frequency band – it is unusable for swimming or under/in-water activities. Since operating on a smartphone, which in the end has got some physical dimensions and weight, the system will also not be helpful for sports competitions. For this, much smaller and less cramping devices similar to small watches are required.

During running, cross-country skiing and all other comparable activities an extra carrier pouch has to be used, which is also part of the delivery package of the used phone (Figure 9). Considering the size and weight of this solution, this obviously cannot be accounted as appropriate solution.

The preferable way for such kind of sports activities would be to run the smartphone as intelligent relay, which is carried, e. g., in a belt or a bag close to the body, and to use in addition a watch-like system worn at the wrist as remote display in terms of software layers of the HR monitor.



Figure 10: Remote wrist display for Android smartphone. This device could perfectly complement the heart rate monitoring UI for endurance sports like distance running.

Such hardware indeed is available for the phone brand, on which the system was implemented for this work (Figure 10). Using this remote display extension would be even more comfortable than sports watches, because it is lighter and has got a colour display and a comparable operational time. At current project state, this concept extension was just started, additional fundamental work will be required especially on the UI aspects, since the display size of the wrist device is much smaller and possible input actions are simplified in comparison to a full smartphone screen. Furthermore, the software needs to be specially designed for low-power consumption; optimization for this aspect was

not regarded in the prototypes that have been developed so far.

The feasibility of this relaying smartphone system was also tested already in this research, but so far only with a few singular experiments. In these tests, the smartphone with the activated HR monitor was carried inside a rucksack on the back, while performing running and inline skating laps (skating test sample in Figure 8). In parallel, the lap routing was recorded with other commercial tracking devices; a comparison of results showed that the difference between the HR distance measure and the other systems was not more than 1%, which appears well acceptable, since the precise Geo tracking is none of the primary scopes of the HR monitor.

Considering sports physiology, there arises a general question with the concept of linking workouts to the MHR. Especially in endurance training, different energy reservoirs in the human body are used in a sequence. During the first minutes, phosphate storage is used, which is located inside the muscles, and low oxygen is required for burning this. Consequently, the heart rate is lowered in the beginning of sports activities. After this – for a phase of approx. 1.5 hours – the body uses carbohydrate burning, which maps in general well to the HR levels in Figure 1. Afterwards, the body tries to supply itself by “fat” burning (i. e. a conversion of fat reservoirs into carbohydrate, which is then used as energy supply for the muscles), if the person is used to it. In this phase, the heart rate starts increasing considerably.

But even in the phase of carbohydrate burning at steady aerobic level, there exists the so-called effect of “cardiodrift” (Dawson et al., 2005). It stands for a continuous, slight increase of HR, which occurs despite a perfectly balanced demand level already for workouts less than an hour. Cardiodrift is not fully understood yet, there even exists some controversial discussion since longer time about its origin, but the effect itself is not under question and hence, it would to be considered in an accurate training regulation as well. The control loops in the developed HR monitor are not prepared yet for compensating this effect, at the current state of research reports it wouldn’t anyway be possible to identify a general mathematical rule for continuously adopting the HR band limits during an on-going workout.

This all implies that HR monitoring doesn’t work well as effort indicator for short workouts, and appears only reasonable with a programmed training plan for longer workouts. Without detail knowledge about these relations or planning support and

guidance from appropriate experts, HR-controlled training units may have only limited effects, when the workouts are too short or too long.

7 CONCLUSIONS AND OUTLOOK

The concept of a user-friendly heart rate monitor has been researched scientifically, and it has been realized on base of the corresponding findings technically. In this system, coloured and analogue display indicators allow perceiving the most relevant heart monitoring information with quick and effortless glances in less than a second. The training range can be conveniently set by one single button touch on top-level screen.

This work represents a knowledge fusion from the areas of human-computer interaction (HCI), mobile computing, human physiology and sports. As result the system is useful for controlled sports training as also for health exercises in a broad application range, where heart rate stands for the effort level. It can be used indoor and outdoor for general gym exercises, strength training, walking, running, cycling and skiing.

Best comfort certainly is reached, when the heart monitor is not carried close to the body, but mounted in best viewing distance and direction. The latter would be achieved easily by commonly available smartphone holders for bicycles and automotive.

For outdoor sports without machines, certainly the current system is sensed as not being optimal due to its size and weight; some additional development would be required to improve it. Although there was positive tendency in the feedback of first friendly user tests, there is no scientifically-based proof behind this assessment about the usability yet. This still has to be validated and the corresponding findings certainly will lead to additional detail improvements.

Already now – in comparison to consumer market devices – the heart rate monitor, which was developed here, is funded on appropriate and modern HCI concepts and it will by that ease the control of sports activities for achieving in the end the desired training results more efficiently.

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