Application of Mobile Technologies in the Preparations for Long Distance Running

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Abstract: Fast development of mobile ICT technologies has enabled and imposed their implementation in many business, private and sport areas. As mobile technologies enable quick and two-way communication, independent of the present location of an athlete, their trainer or expert hardware and software systems, it is of the significant importance to utilize the advantages of that kind of communication in order to maximize the chances of achieving excellent results in a specific training process or in a key race. In this paper is shown one ORT (Online Running Trainer) system, which was developed for preparations of long-distance runners. It describes a new algorithm for calculation of training equivalents of set and achieved trainings, which was used for the success analysis of every micro cycle of the training process. By using all available telecommunication channels, ORT system communicates with its users in real time. Moreover, it analyses their performance and, if necessary, dynamically corrects their training parameters in order for them to achieve better results in a needed moment. Described methods and procedures are verified on a selected sample of marathon runners.

1 INTRODUCTION

Nowadays, modern mobile ICT technologies follow up an athlete in all stages of their preparations. It helps him in developing a program of their preparations, ensures him an access to important information in the right moment and enables the storage of current parameters and information related to training process or to a particular training. Major expansion in the development of mobile phones of all sizes, with great processing capabilities, affordable prices and intuitive user interface, has made the users of all sport, psychological and cognitive categories capable of using telecommunication services during the indoor and outdoor workouts. In that way, there are possibilities of an individual approach to a single athlete, regardless of their current location, and the communication between the athlete and their coach or between the athlete and the system that cares for athlete`s results is facilitated. In a situation where there is an expert system that has the ability to generate a program for athletic preparations and the ability to evaluate given and performed trainings in real time, mobile telecommunication channels become dominant communication platform between the system, a coach and his athlete.

In this paper is shown one such system which helps long-distance runners in developing their program for preparations, and by using available mobile ICT technologies it stores, analyzes the information and advices them in real or near-real time. Ineffective trainings are dynamically changed with solutions that are safer and that faster lead to the preferred result, with lesser chance of sport injury. The second part of this paper describes the architecture of one "Online running training system" (ORT), while the third part of the paper shows telecommunication platform which is used for two-way communication with users. The fourth part of the paper describes the methods and algorithms developed for evaluation of given and performed workouts in the preparation program for 5K runners to marathon runners. In the fifth part is described and shown the verification of results on a selected sample of marathon runners. The final part of the

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paper gives a conclusion and the list of references.

2 REPRESENTATION OF ORT SYSTEM

The prototype of the system was developed by using open-source programs (PHP, MySQL, Linux). The whole applicative solution was launched on the Linux distribution of CentOS 6.4, version 5.3.3 of objectively-oriented PHP language, on MySQL server relational database distribution 5.67 (MySQL, available at: http://www.mysql.com, accessed on 07 July 2013), and on Apache web server 2.2.15. Individual applications are run by cron (crontab, cron table) service.

2.1 The Architecture of an expert System

The first display which users of prototype of ORT system encounter is shown in the Figure 1.

Figure 1: Opening display of prototype of ORT system (in Croatian language).

During the registration process, users define their user name and their password, they enter their personal info, the number of their mobile phone and their e-mail address where they receive an activation link. Due to the security reasons, user's password is encrypted with MD5 algorithm, 128-byte cryptography hash function, ratified Internet standard RFC 1321, and in that form it is being stored in the database. When the user has successfully logged in, he or she is presented with an appropriate menu, in accordance with his or her authorization levels. A specific part of the menu functions/options is shown or hidden from the user.

2.2 Generating the Training Program

One of the frequently used functions of the system is "Program generating". The main task of that subsystem is to create a program for preparations of long-distance runners for following distances:

- 5000 m (5K)
- 10000 m (10K)
- 21097 m (half marathon)
- 42195 m (marathon)

After the user enters the results of his/her current sport capabilities (race or training), the system calculates their maximum aerobic capacity ($VO2_{max}$ factor), which serves the purpose of estimating runner's potential on the races from 800m to marathon, which is going to be used in the future workouts. Then the runner selects a specific discipline for which he intends to prepare, the length of the program (between 12 and 24 weeks), the starting date, selects the upper limit of the acceptable weekly mileage and decides on the toughness of the program (Program A – beginners), (Program B – advanced) or (Program C – elite). The opening display for entering the parameters needed for generating the program is shown in the Figure 2.

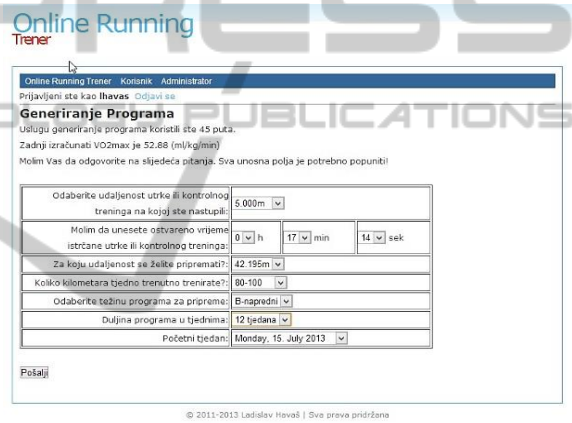

Figure 2: Entering the basic parameters for generating the program (in Croatian language).

2.3 Running Log

All the done workouts the user can and should inscribe in the second important module called the "Running Log" by using the available telecommunication channels and by doing so enable evaluation and the comparison of envisaged and performed workouts.

Selecting the appropriate day and the input of relevant data is possible to render in real time, during the workout or immediately after the workout, but also backwards, which allows the user to completely fill in the Running Log in order to get the review of your performance as detailed as possible. Aside from the usual track of each workout (when, how much, how fast, the type of training…), the user has the ability to mark their own training based on their biased perception (tiredness, lack of sleep, humidity, temperature, wind and other

aggravating factors) through VAS scale (Visual Analog Scale), which is known as a frequently used medical psychometric method that has been used for evaluating the sense of pain. That scale enables the choice of values between 0 and 10, wherein 0 would stand for ideal conditions for a workout and values closer to 10 would stand for less ideal conditions, thereby done workouts should be also assessed in accordance with appropriate correction factor. With the possibility of inputting the data through web (version 2.0), other methods have also been developed which use mobile telecommunication channels and allow the user to communicate with ORT system in real or almost real time through e-mail (smart phones) or through SMS.

3 THE ARHITECHTURE OF THE TELECOMMUNICATION PLATFORM

A telecommunication system was developed which has the purpose of enabling the exchange of information in real time with the users through several different telecommunication interfaces.

The information which the users exchange with ORT system have to be in a specific format which is set by the protocol for exchange of the data that is to be mentioned in the following parts of this paper. All information which, through different mobile channels, arrive to the system are being stored in the Running Log. From there they are periodically filling by ETL process (Extracting, Transforming, Loading) into the data warehouse, and after extensive analyzes users can inform themselves about the quality of their workouts in the past period of time. The flow of information between the user and the system is shown in the Figure 3.

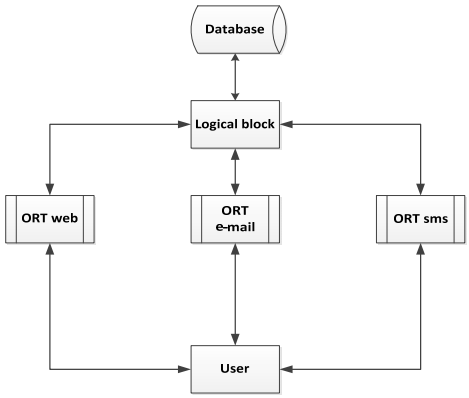

Figure 3: The flow of information between the modules of the system.

From the Figure 3 can be seen that there are supported following methods for exchange of data between the user and the database:

- Web
- E-mail
- SMS

By using different Internet browsers (Firefox, Google Chrome, Opera, Safari…) users inscribe their done workouts into the system, for the purpose of their use in the feedback analysis. In case of the e-mail method the users use available e-mail clients, which they sent their e-mail messages to. The advantage of this method lies in the fact that the majority of smart phones support e-mail function through some of available e-mail clients. In that way an interaction between distant users and the ORT system is enabled, provided that on a particular location there is a signal of one mobile network. SMS, as a third method for exchanging the information, enables the communication in real time with the users that are owners of older cell phones which do not posses an e-mail function. The limit of this communication method lies in the fact that the upper limit of characters in one sms is 160. In the follow-up, mentioned methods will be thoroughly presented.

3.1 ORT Web Module

By using the Web module, it is possible in a simple and intuitive way to develop a communication with a Running Log. By launching one of available Internet browsers and by entering the appropriate menu of ORT web application, one is able to update the Running Log. In the Figure 4 it can be seen the opening display which a user sees upon entering.

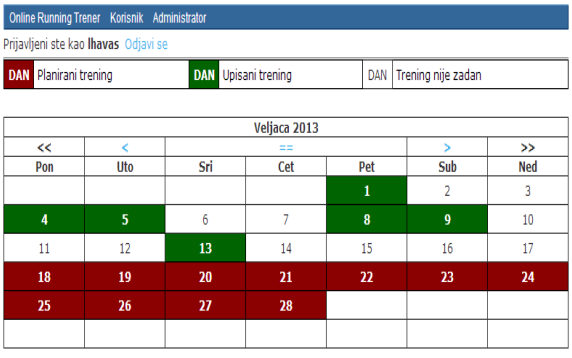

Figure 4: Running Log (in Croatian language).

It always shows the current month, but there is a possibility of going backwards, in case a runner wants to inscribe some new information or to update

the existing ones.

Boxes labelled with red stand for the days in the month for which the user has been given a particular workout, but still has not inscribed feedback information on that particular workout. Boxes labelled with green stand for the days in the month for which the user has inscribed feedback information, whereas white boxes stand for the days when there is no given workout. Using the Web interface is the main method for determination and the analysis of given and done workouts. Other telecommunication channels such as e-mail and SMS are used in order to provide the runners with the ability to directly communicate with the application during or immediately after the workout.

Access to the Web interface is enabled through HTTP protocol (Hypertext Transfer Protocol). HTTP protocol is the protocol of application (seventh) layer of OSI model (Open Systems Interconnection) and functions by using "Request-Response" method in which the Web server and the client participate.

On a server which runs ORT application is installed and set *Apache2* Web server. That Web server is always active and awaits new requests on a network port 80. Upon receiving new HTTP request which is initiated by a client, ie. user of a Web browser, web service will, from local disc, reach predefined data files inscribed in the form of HTML (HyperText Markup Language) record which presents ORT Running Log.

One such transaction is shown in the Figure 5. This type of joining the database is impractical for mobile phones with small displays.

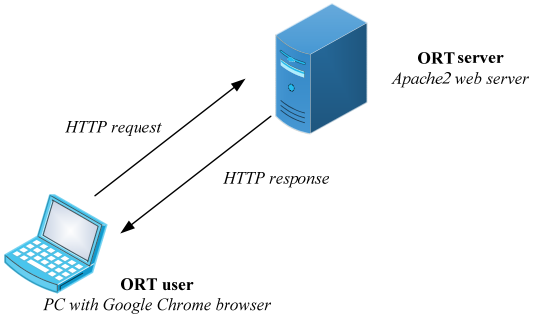

Figure 5: HTTP transaction.

3.2 ORT e-Mail Module

This module is used for processing and sending e-mail messages. For its work it uses IMAP (Internet Message Access Protocol) and SMTP (Simple Mail Transfer Protocol) protocols. Module is, at very high frequency and through IMAP protocol, connects to a mailbox of an electronic mail of ORT system in which it finds e-mail messages of the users. The system will, in accordance with programmed protocol for exchanging the information, check the accuracy of information and will notify the user on the outcome of his request through SMTP protocol.

An example of the transaction performed through ORT e-mail module:

User inquiry:

```
From: lhavas@velv.hr
To: ort.trener@gmail.com
Subject: ?
```

A response from ORT system:

```
From: ort.trener@gmail.com
To: lhavas@velv.hr
Subject: ORT Help
Dear user,
Welcome to ORT system for training
login through e-mail. In order to
receive help for a specific type of
training please enter one of the
following phrases in the SUBJECT of an
e-mail message on the address
ort.trener@gmail.com:
I? - for an interval training
S? - for a superset training
T? - for a tempo training
L? - for a prolonged training
R? - for a recovery training
X? - for an alternative training
Example: Subject: I?
Kind regards,
Your ORT!
```

In case the user, for example has done an interval training according to given instructions, it is possible to inscribe the training in the database through an e-mail in the following way:

```
From: lhavas@velv.hr
To: ort.trener@gmail.com
Subject:
#I*400*00:01:30*10*120*12000*60*180*120
*145*980**7*demo training example#
```

All successfully registered trainings are inscribed in the database in real time in the Running Log.
The next example shows an e-mail communication between the user and the ORT system in details:

An e-mail client, which is installed on the user's cell phone will connect, through SMTP protocol, with one of the outgoing e-mail servers and issue a request for sending an e-mail message of the predefined content. That e-mail server will parse an e-mail address on *local-name@domein* and will, based on that, draw a conclusion in which domain the user is located. Through DNS (Domain Name System) request, it will ask for MX (Mail

Exchanger) record of the domain, whose response will provide it with the information on the list of names of serves and associated priorities for the domain in concern. E-mail server with the lowest priority will be the destination on which prior listed e-mail servers will send message to. When that message is being delivered to the destination server, it will be reachable in the user's mail box IMAP protocol, which is shown in the Figure 6.

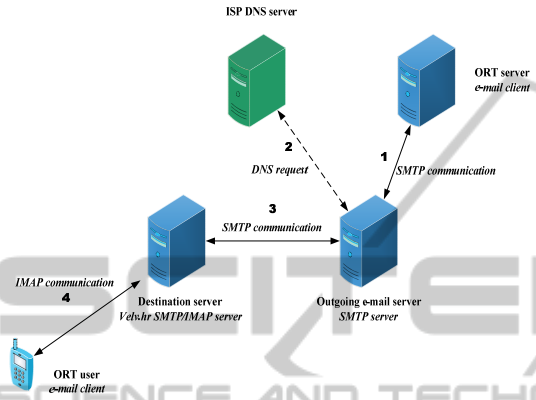

Figure 6: Display of e-mail communication between the ORT server and the ORT user.

3.3 ORT SMS Module

The ORT *SMS module* is used for communication with the users whose mobile phones do not support e-mail function. With the fact that one sms is limited to 160 characters, the main flaw of this subsystem is in its unprofitability in regard to free and as fast e-mail messages. ORT system sends SMS messages by using SMS service called *Clickatell.com*.

Clickatell.com SMS service accepts HTTP request whose URL (Uniform Resource Locator) address possesses all needed information for sending SMS. As a HTTP response on the previous HTTP request, one receives a confirmation whether a message has been successfully sent. When Clickatell.com through HTTP protocol takes over all necessary information, SMS is, in accordance with the request, directed all the way to the telecommunication mobile operator on which there is a mobile phone of the ORT user.

4 EVALUATION OF THE TRAINING QUALITY

Dynamic management of training process is impossible without methods and algorithms for evaluation of the quality of given and performed workouts. The following segments of this paper will briefly describe the methods for calculating the numeric equivalent of basic training elements in the athletic preparations of marathon runners. Firstly, an algorithm for determining the training equivalent of given trainings will be described, then the procedure for evaluation of done training will be described.

4.1 Given Trainings

Long Run:
Long Run is the basis of all programs for long-distance running, and especially of the program for preparation of marathon runners (Havaš and Vlahek, 2006). The effort should not be too high as one should run in the aerobic zone.

Due to the above-mentioned reasons, for each 15 minutes of running, ORT system adds 5 points to the total training equivalent.

Tempo Training:
During the determination of training equivalent in tempo training, potential of the user is also taken into consideration along with the duration of the training, in regard to his currently calculated maximal aerobic capacity $VO2_{max}$.

In case that a tempo training means running in the tempo of a marathon, the duration is calculated in seconds and compared with the anticipated capabilities of that particular runner. Calculated training equivalent is a percent of the training duration in seconds in regard to maximum duration in seconds which is anticipated for a user based on his anticipated result. Anticipating the potential is realized by a method of dr. Daniels and Gilbert (1979).

Speed Training:
From many known speed trainings, in ORT system are used Interval training and Super set training.

The first step is to calculate the percentage of the run distance at the given tempo. In case one runs at the tempo of 5000m race, and one runs 4000m (10 x 400m), that implies training equivalent of 80%, or 80. That equivalent is decreased 0,5 points for every 15-second break between intervals.

Recovery Training:
Recovery trainings are not physiologically demanding, which means that during the calculation of the training equivalent only the duration in the 15-minute intervals is calculated. Every hour of such training gives the runner 20 points to the total training equivalent.

4.2 The Analysis of Done Trainings

When the database receives the data from done trainings, it is also necessary to calculate their training equivalent. Methods that are explained for calculating the training equivalent are used, although some new parameters are also introduced, for the purpose of even more detailed evaluation of achieved effects.

Aside from all known parameters that are used in trainings and serve the purpose of calculating the training equivalent (speed, duration, distance, number of trials, duration of recovery periods etc...), the user has the ability to inscribe some additional values:

- HR – maximum, minimum or average heart rate during the training
- Kcal – burned calories during the training
- Lactates – concentration of the lactic acid in the blood
- VAS - subjective estimate of the training conditions (temperature, humidity, wind, biorhythm, tiredness, lack of energy…)

Every one of those parameters influences the quality of the evaluation of done trainings.

HR (Heart Rate):
Each user should (by using some of the suggested methods (Heart rate training zones, available at: http://www.brianmac.co.uk, accessed on 01. April 2013)) calculate their maximum heart rate and inscribe the data into the ORT system. By knowing the maximum heart rate of every user (HR_{max}), it is possible to estimate has the particular user resided in a specific HR zone, which is usual for that type of training.

Particular trainings and running tempos of a certain part should be done within one of the zones (Polar sport zones for running, available at: http://www.polar.com/en, accessed on 29. December 2012):

- Zone 1: 50-60% of the maximum heart rate (very easy, daily activities)
- Zone 2: 60-70% of the maximum heart rate (easy activity, fat burning zone)
- Zone 3: 70-80% of the maximum heart rate (aerobic zone, a moderate effort)
- Zone 4: 80-90% of the maximum heart rate (anaerobic threshold)
- Zone 5: 90-100% of the maximum heart rate (very intense, competitive training)

In case a particular type of training is done within the appropriate zone, it is not necessary to correct the calculated training equivalent. For every jump to a lower or to a higher zone, the system calculates +/- 20 points to the training equivalent.

Calories (Kcal):
There is no exact method which would allow for a precise calculation of how many calories a runner of a certain weight, sex and years of age consumes at a certain speed of running in a particular period of time or a duration interval. On top of that, it has been noticed that there is a specific correlation between the heart rate and the consumption of calories for user. One of the more quality methods that takes into account above-mentioned parameters as well as maximum aerobic capacity has been suggested in (Keytel, at al., 2005) and it was used in the prototype of the ORT system for calculating the number of consumed calories. In case where the maximum aerobic capacity $VO2_{max}$ of an individual is known, then:

formula for men is:

$$((-95.7735 + (0.634 \times HR) + (0.404 \times VO2_{max}) + (0.394 \times W) + (0.271 \times A)) / 4.184) \times 60 \times T \quad (1)$$

formula for women is:

$$((-59.3954 + (0.45 \times HR) + (0.380 \times VO2_{max}) + (0.103 \times W) + (0.274 \times A)) / 4.184) \times 60 \times T \quad (2)$$

Where is:

HR = heart rate per minute
W = weight in kilograms
A = age in years
T = duration in hours
$VO2_{max}$ = max. aerobic capacity in ml/kg/min

Lactates:
The speed of creating lactic acid is proportional to the speed of running, ie. it is proportional to the percentage of used maximum aerobic capacity. For the trainings that are at marathon tempo, the concentration of the lactic acid should not be crossing the level of 2mmol/L of blood. For the runs that are at the tempo of half-marathon, it is predicted that lactates do not cross the level of 4 mmol/L of blood, while for the runs at the tempo of races on 10000, 5000 and 3000 meters, the concentration of the lactic acid is significantly higher than 4 mmol/L of blood. Every discrepancy from the prescribed intervals, the ORT system evaluates with the correction of the training equivalent by +/- 15 points.

VAS (Visual Analogue Scale):
In the ORT system it is used as a unique indicator of the quality of the training conditions. For all values between 0-4 it is considered that the conditions were

adequate, and accordingly the training effect remains unchanged. For each value higher than 4, calculated training effect is increased by 5 points.

Mentioned values can be subjected to certain changes for the purpose of increasing the quality of training evaluation. Since the developed system has the ability of self-learning, those parameters will be changed in time to more optimal values of those factors.

5 VERIFICATION AND ANALYSIS OF THE RESULTS

5.1 Verification of the Results

Developed system for generating programs and the mobile surveillance of the quality of the training process has been verified on a selected sample of marathon runners, which allowed for an evaluation of the quality of implemented methods and algorithms, for the purpose of correcting or updating, if necessary, some of the methods used. Selected and analyzed were the runners of both sexes and in the age range from 18 to 65.

The number of people who have fulfilled all of the above-mentioned conditions is 58. Among that group there were some beginners, some advanced runners and some were the elite runners who have won many marathons and ultra marathons.
In the Table 1 is shown one part of the users who have participated in the process of the results verification. For the sake of easier statistical analysis, all time measures into seconds.

Table 1: Display of one part of verified users and their results.

No.	Sex	Year of birth	VO2max (ml/kg/min)	Planned result (s)	Achieved result (s)
1	male	1966.	59,32	2:49:00 (10140)	2:55:21 (10521)
2	male	1987.	33,48	4:28:00 (16080)	4:31:22 (16282)
3	male	1970.	56,32	2:55:00 (10500)	3:02:12 (10932)
4	male	1994.	43,12	3:40:00 (13200)	3:38:19 (13099)
5	male	1983.	30,82	4:45:00 (17100)	4:52:11 (17531)
6	female	1982.	50,52	3:09:00 (11340)	3:07:20 (11240)
7	male	1978.	49,22	3:10:00 (11400)	3:08:40 (11320)

5.2 Statistical Analysis of the Results

IAAF (International Association of Athletics Federations) evaluates runners and their results in 5-year classes, and in this paper the runners and their results are evaluated according to their sex and whether they are between 18-29, 30-50 and more than 50 years of age. Moreover, they have also been assessed according to toughness level of their preparations. Program A (marathon slower than 3:30:00), Program B (marathon between 3:00:00 and 3:30:00) and Program C (marathon faster than 3:00:00).

For the analysis of included data, a descriptive statistical analysis was used (Lipschutz and Schiller, 1998), while for the graphical display of data distribution there were used rectangular diagrams (Box and Whisker plot). Statistical processing of data has been done by using a mathematical applicative programme "Matlab 7.0.1" and the application Microsoft Excel 2013. Statistically significant in the analysis were confirmed discrepancies at the significance level of $p<0,01$.

Athletes included in the research were old, on average, 34,16 years, wherein the standard deviation is 9,87 years. Range of variation has the value of 47 since the youngest participant is 18, while the oldest is 65.

During the research of correlation between achieved and planned result, Pearson's coefficient of correlation has been calculated. Based on the value of the coefficient of correlation and the p-value derived during the testing of the hypothesis on statistical significance of the analyzed variables ($r=0,9926$ i $p=0,0000$), it can be concluded that there is a statistically significant positive correlation between the observed variables. The graphical display of the correlation between achieved and planned result is given in the Figure 7.

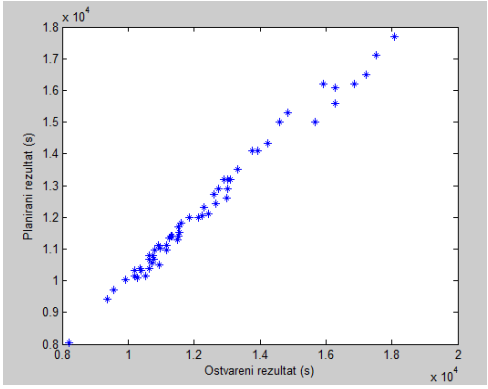

Figure 7: Correlation between achieved and planned result (in Croatian language).

Distribution of the data obtained during the research has been verified with "Kolmogorov – Smirinov" test. Since the distribution of the data substantially deviates from the normal distribution, for calculating statistically significant discrepancies between the three groups has been used non-parameter (Kruskal-

Wallis) test. The results of the Kruskal-Wallis test, which relate to planned time for the programs A, B and C indicates that there is statistically significant difference in planned time between the groups (*H=50,4978* and *p=0,0000*). Test for multiple comparison has confirmed that all three groups (three toughness levels) are statistically substantially different. In order to achieve that kind of results, in more than 50 % of the users it was necessary to dynamically modify the training process.

Figure 8 gives a graphical display of the drawn conclusion from a statistical test.

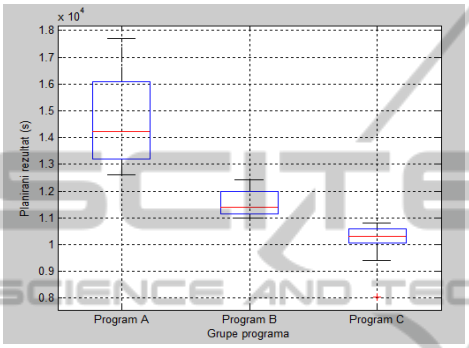

Figure 8: Planned result (s) in regard to different toughness level (in Croatian language).

All necessary corrections of implemented algorithms and the evaluation of particular training elements were automatically implemented into the system.

6 CONCLUSIONS

This paper shows modelling of a system for mobile telecommunication support in athletic preparations of long-distance runners. This is a very complex area which is intensively growing and in the future is going to be a subject of many analyzes and the opportunity for implementation of new ideas and algorithms.

Here was described one telecommunication platform which in real time communicates with athletes, evaluates their given and done workouts, and, if necessary, dynamically modifies the rest of their training process for the purpose of achieving better results. Functioning of an expert system which generates programs for preparations in popular long-distance disciplines (5000m, 10000m, half-marathon and marathon) was presented in this paper. Developed system is dimensioned for simultaneous interactive use by a large group of users. Flexible environment was created which protects the individuality of each athlete, who decides on their own on the volume of their training, the starting date, toughness level as well as chooses one of the available telecommunication channels for the data transfer. As opposed to many other web services and available books, at this point there it does not end the interaction with the developed system. Database and the data warehouse were formed which are being updated in real time and the algorithms for evaluation of given and done trainings have also been developed.

Research on this topic has been directed at integration of all above-mentioned segments, generated program and the feedback information in the shared database, by using mobile telecommunication channels for data transfer in real or almost-real time. Verification of the algorithms and the methods has been conducted on a limited sample of marathon runners. The procedure of verification where the database and the data warehouse have been filled with new quality data on daily basis has led to enabled self-learning and constant improvement of implemented algorithms for generating programs for evaluation of results.

By a modular concept of the database the data warehouse and by using the technologies and the tools of open-source codes, it is relatively easy to extend the system with new hardware and software modules.

The procedure of verification has shown that dynamic correction of generated programs in real time, by using ICT technologies and implemented algorithms and methods, substantially decreases the probability of not achieving adequate result with the increased probability of achieving the desired result in optimal conditions.

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