Outline of a Qualitative Analysis for the Human Motion in Case of Ergometer Rowing

ANTE PANJKOTA, IVO STANČIĆ, TAMARA ŠUPUK
Laboratory for Biomechanics and Automatic Control Systems
Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture – FESB, University of Split
Ruđera Boškovića bb.
Croatia
apanjkot@unizd.hr, ivo.stancic@fesb.hr, tamara.supuk@fesb.hr

Abstract: - Today, there are numerous methods of quantitative analysis of the human movement. Basic quality of these methods is the high degree of accuracy and reliability of the obtained data. According to systematic approach human movement is qualified as a complex system that is, as such, subject to the principle of incompatibility (Zadeh, 1973) - i.e. making precise assertions is in reciprocity with their significance for the system. In this paper the outline of a method for qualitative analysis of human movement in the case of ergometer rowing have been proposed. Qualification process of kinematic parameters is done on the basis of previously collected quantitative data and with possession of prior contextual knowledge for their qualification by rowing experts. Possible applications of the proposed method, as well as guidelines for method improvement are briefly discussed.

Key-Words: - qualitative analysis, quantitative analysis, fuzzification, rowing, human motion

1 Introduction

In last few years, human motion analysis is one of the most studied fields in the science. Thus huge scientific attention come from a large number of examples from the real world in which human movement has a central role. We'll mention only some of the most important - sports (improving the performance and specific sport technique, as well as prevention of the injury), man - machine interface, ergonomics of the working places, smart surveillance, virtual reality, intelligent medical robotics, entertainment industry, etc. For this purpose numerous quantitative analysis methods of the human motion have been developed [1], [2], [3].

Generally, human motion can be divided into a body or body segements detection, tracking and activity understanding [4]. For this purpose 2D or 3D approaches have been used, i.e. the recording with one or more cameras. Models of the body or body segments are in range from various stick figures, over 2D - contours to the volumetrics representations. Parameters for kinematics analysis can be obtained by using active or passive markers, and by efficient markerless algorithms for human motion tracking which have been recently developed [5] or applying inertial sensors techniques [6]. All of these methods are characterized by relatively high degree of accuracy and precision, as well as reliability of the collected data.

On the other hand, the quantification in most cases is in contrast to the way of thinking and formulating solutions by experts from the particular domain of motion study - such as coaches, doctors, physiologists, psychologists, etc. Increasing the precision of quantitative data necessarily leads to reducing of their importance for the end users , which is in accordance with the principle of incompatibility [7].

In order to be more useful for human experts, quantitative data obtained by advanced and reliable methods of the human motion analysis can be subjected to the process of qualification. This means that it is possible to switch to qualification analysis of the human motion when the situation demands thus. On this way these two methods become mutually complementary methods. In what follows, we shall propose some basics aspects of qualitative method for the human movement analysis in case of ergometer rowing. As a matter of fact, this paper is not presenting the full and final exposition of our approach and its applicability. Rather, it should be regarded as an rudimental outline of a method which has different approach in relation with the classical quantitative methods. Theoretical foundation for qualitative analysis nowadays is a well known and mathematically precisely defined, and it is represented with the Fuzzy set theory, Fuzzy logic, CW (Computing with Words) theory, Fuzzification, Fuzzy graphs, Fuzzy information granulation and General Theory of uncertainty (GTU) .

2 Konceptual framework for qualitative human movement analysis

Usually at motion analysis, observed movement is divided into several phases. Depending on the complexity of the movement any or some phases can be additionaly divided into sub phases. Each phase or sub phase is described by the experts. Number of phases varies even for the description of the same movement. Generally, there is no consensus among experts nor scientists which division to accept. The main reason for that is in the approximative equal number of given pros and cons arguments for those that dominate in the literature. Thus, in rowing, there are divisions on 3, 5 and 7 phases. We accepted 5 phases division of the rowing stroke, respected recommendations of an rowing coaches with whom we were cooperated. According to the that division rowing stroke is divided into the following phases:

1) catch
2) drive
3) finish
4) release
5) recovery

First three phases represent the active part of the stroke, while the last two are passive part. Let's look at how one of the experts[8:173] described finish:

> „At the finish the legs and back finish together. The legs lock to stabilize the end of the stroke. With the hips locked and back braced, the arms can pull strongly....“

Or part of description for recovery phase [9:14,15]:

> „...The aim should be to extend the arms until they are straight, to pivot from hips until the body is in the correct position for the catch, and only then to start breaking the knees to slide forwards.“

Similar descriptions can be found for human gait or another movements. It is obvious that the experts are using qualitative descriptions and that was main reason why we have decided for qualitative approach of human movement analysis.

For the purpose of qualitative analysis acquisition of data and its computer processing is needed. We can freely said that classical quantitative methods are base for the proposed qualitative analysis. After that first phase it is necessary to make transformation of the selected variables in the qualitative domain. In this step we use a knowledge of the experts to determine the limits within which the linguistic variables are defined and associated hedges. In fact, on this manner we have made fuzzification of the input acquisition parameters. Still remains to determine the memebership function that best fit a given case. On figure below (Fig. 1) a conceptual representation of the qualitative analysis is shown:

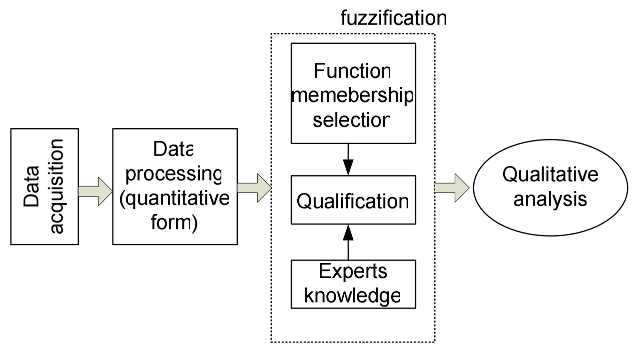


Fig. 1 Conceptual framework for qualitative analysis of the human movememt

If the body is viewed as a system of linked segments [10], [11] then, for any segment BS (body segment) following parameters can be defined:

$$BS\_n \rightarrow lp\_n;\ lv\_n;\ la\_n \mid n = 1,2,3,\ \ldots \qquad (1)$$

And / Or

$$BS\_n \rightarrow anp\_n;\ anv\_n;\ ana\_n \mid n = 1,2,3,\ldots \qquad (2)$$

Where is:

lp_n .... linear position of the nth body segment
lv_n .... velocity of the nth body segment
la_n .... acceleration of the nth body segment
anp_n .... angular position of the nth bodysegment
anv_n .... angular velocity of thr nth body segment
ana_n .... angular acceleration of the nth body segment

As we can see the linear and / or angular variables of each segment might be defined. Also some other variables, such as position of the one segment with respect to another (relative position), could be defined if needed. Linguistic variables [12, 13], which are used for description of motion, are defined by taking into account the upper division on the linear /angular and relative variables, so we have:

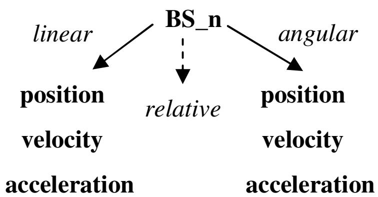


Fig.2 Lingvistic variables of the particular body segment

If for an example, the trunk is observed BS_n then one of the relevant linguistic variables is angular position, which can take values extremely sloped, very sloped, moderate sloped, gently sloped, upright, etc. Introducing direction in analysis we will have forward and backward. Fuzzification takes place based on the knowledge of experts (desirable not only one), so that the area of a set of crisp values is transformed into fuzzy set. The whole process can be summarized in the following steps:

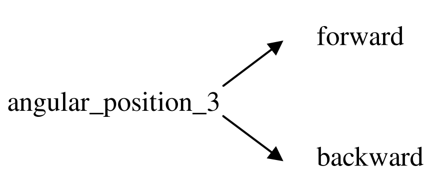
1) Pick up segment – e.g. BS_3 ≡ trunk

2) Membership function selection

3) Determining the lingvistic variable – for example:

   anp_3 → angular_position_3

4) Defining of the primary terms for the lingvistic variable:



5) Determining the lingvistic variable values together with experts:

   forward = {value_1, value_2, value_3, ..., value_n}

   backward = {val_1, val_2, val_3, ... , val_m}

   n,m ∈ $\mathbf{N}^+$

6) If necessary specify the **negation** and connectivenes **and** and **or**

7) Repeat the whole procedure for different memebership function election

This procedure should be repeated for all parameters of interest in the analysis of an observed movements.

3 Methodology

The proposed method is based on fuzzification of the collected and processed variables of observed movement on rowing ergometer. Digital video camcorder – PC system was used for recording marker positions attached on eight crucial points in sagittal plain [14].

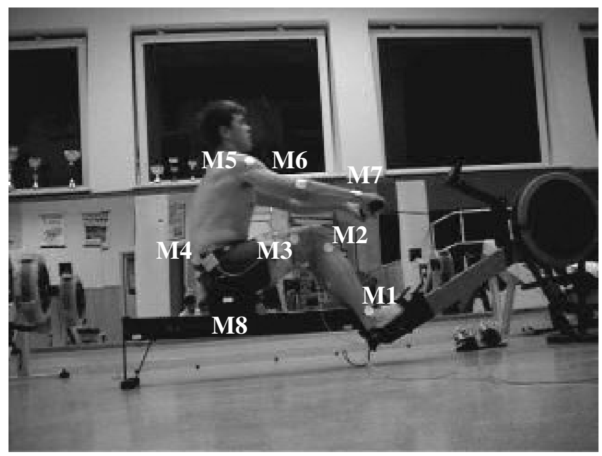


Fig. 3 Rower with marker positions pointed out

Marker tracking was done by program written in C++ which elaborate recorded video and produced a Matlab compatible file (matrix) containing coordinates of each marker recorded throught time. This program is able to use different types of correlation or Walsh trasformation to follow selected markers on sequence of frames. It also relies on simple prediction of next position of the marker [15]. The markers were placed on each rower, from whose coordinates, the data necessary for kinematics analysis of the stroke were obtained (Fig. 3). Processing of the obtained marker positions by means numerical differentiation were done in order to attain the linear and angular velocities and accelerations. The curve smoothing and their graphical representation were done in Matlab program package.
In the second part experts are consulted (in our case, two coaches in the lower categories and coach in junior team of the Croatian rowing team), and rowing stroke phase exposition, as well as available rowing technique

descriptions available in the literature [8, 9, 16] in order to fuzzification of the obtained data could be conducted through the steps 1) - 7) described in paragraph 2 of this work. Fuzzification and accompanying data processing was performed using the Matlab Fuzzy Logic Toolbox and Simulink [17], [18], [19], [20].

4 Results and discussion

Analysis and description of the quantitative data that can be transformed into a form suitable for qualitative analysis by the process of fuzzification might be found in papers [21] and [22]. Figures 4 and 5 are typical examples of the quantitative analysis data depiction.

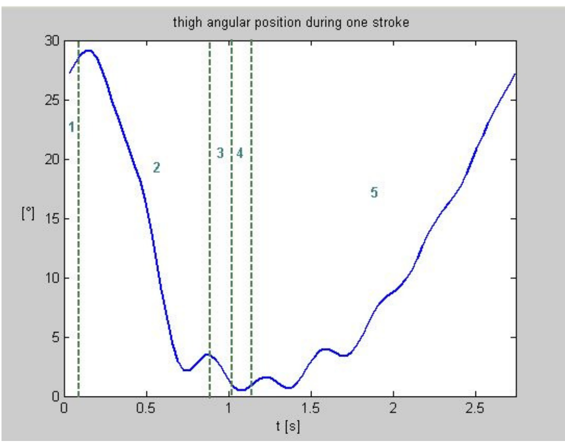


Fig. 5 Thight angular position during one stroke

Labels 1 – 5 attached on figure above (Fig. 5) represents rowing stroke phases: catch, drive, finish, release and recovery, respectively.

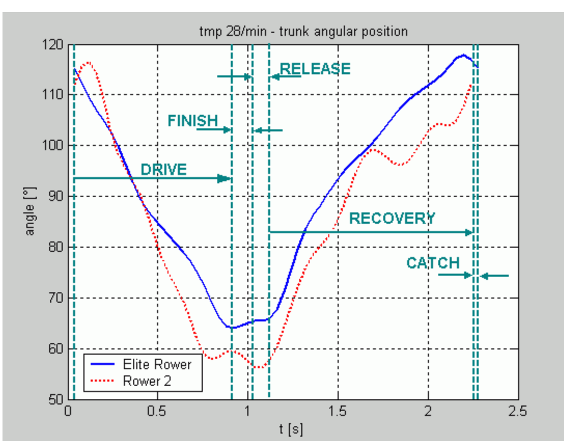


Fig 6 Trunk angular position of one rower from the test group an an elite rower

As the measure of kinematics data deviation in all comaprisons relative error has been calculated.

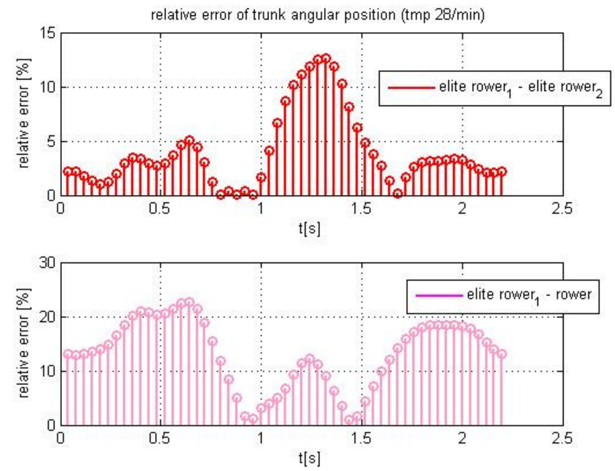


Fig 7. Relative errors for trunk angular position (tmp 28 / min)

In the performed analysis each segment has been observed separately and for the initial consideration trapezoidal membership functions was taken. On the basis of the collected data experts have defined the linguistic variables and their associated values.These results are compared with descriptions of the rowing stroke in an available literature, and according with that a less additional corrections of certain values was done. For example, the lingvistic variable angular_position is defined for trunk. Primary terms forward and backward, which refered to the trunk slope during rowing stroke in relation to the chosen referential coordinate system, were elected. Values of the linguistic variables (hedges) are {very sloped, moderately sloped, gently sloped, upright). Defined values are different for every selected primary term. Fuzzification result of the trunk angular position for randomly chosen rower from the test group and an elite rower is shown on figure below.

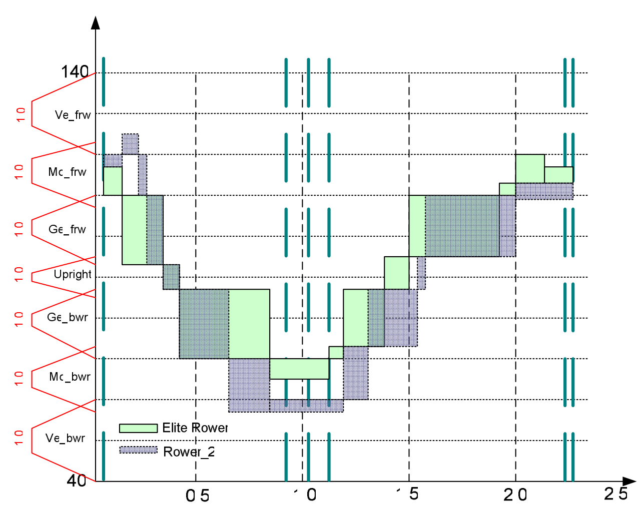


Fig. 8. Results of fuzzification for trunk angular position quantitative depicted on Fig. 6

These results indicates a partially incorrect body position in the initial phase of the drive, completely unacceptable backward slope of the body in the second part of this phase and throughout the whole finish and release phases of the stroke. In recovery phase of the rowing stroke trunk was too much in the open position for that phase. This results in improper catch tilt of the body - generally a rowing experts this case call an unprepared catch position.

Thus obtained preliminary results are evaluated positively by the rowing experts who consider it very usable for the qulitative analysis of the rowing stroke.

5 Concluding remarks

Presented method is an introductory outline of a qualitative analysis for the movement analysis in case of ergometer rowing. Such analysis could provide a tool for practical evaluation of the quality of the rowing technique in each phase of the stroke. Prerequisites for application of the IF - THEN rules for the rowing movement performance rating as a whole, and not only through particular segments have been created. Also, possibility for automatic rowing stroke phases detection are opened. There are good assumption for applicability of the proposed method in analysis of other human movements, not just in rowing case. However, further researching need to be done in regard to this. Improvements of the method in the first place are possible by chosing different memebership functions and by more detailed analysis through the application of the Computing with Words theory and the General Theory of Uncertainty.

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