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SIMULATION MODELS OF THE LONG JUMP

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Abstract: *The aim of the present paper is to present the simulation on long jump trial for two different athletes based on relations found in literature and on recorded data on trials. There are presented some theoretical considerations about the long jump trial and there are mentioned two relations for calculating the length of the jump. Based on experimental data there are simulated the length of the long jumps. The simulated results are compared with the official data and there are presented some conclusions*
Keywords: *long jump, simulation, dynamics of long jump*

1. INTRODUCTION

The long jump trial can be considered one of the pure athletic as long as there are developed some specific abilities. Any jump, as a consequence of the athlete motion is a non-cycle action. The long jump consists of four distinguished phases: the run-up, the take-off, the flight, and the landing [Bur 10], [Gev 07], [Hay 78], [Ion 07], [Mih 08], [Pop 83]. Each phase has, alone, its influence on the length of the jump but in the same time there are connections between them.
A good performance generally is tied of a high value of the horizontal velocity at the end of the run-up, in the moment of the take–off. The moment of take-off is the moment when start to be developed a vertical component of the velocity that increase in the same time with the decreasing of the horizontal component. During the flight the technique of the athlete is dominant being necessary to be developed a self control of the forward rotation produced at the take-off moment.

2. THEORETICAL CONSIDERATIONS

Mechanical models for long jump are focused on obtaining a better value of the jumped distance. Generally, there are two types of models: a model based on the motion of the mass centre and another one based on multi-body theory.
In the case of the first model, after the moment of take-off the athlete is studied by the position of the mass centre and the study of the motion becomes a study of the projectile trajectory.
The studies are done considering two conditions: first without taking into consideration the effect of the air resistance and the other one considering this effect.
The total official distance of jump (figure 1) is given by the relation [6]:

$$d_{official} = \mathrm{d}_{\text{take-off}} + d_{flight} + d_{landing} \tag{1}$$

According with [9], [1], [3] and [5] it is mentioned that in the phase of flight the effect of the gravity is larger than the effect of the aerodynamic forces and the flight distance can be found using the relation:

$$d_{flight} = \frac{v^2 \sin 2\alpha}{2g}\left[1 + \sqrt{\left(1 + \frac{2gh}{v^2 \sin^2\alpha}\right)}\right], \tag{2}$$

where v represents the take-off speed, ¯ is the take-off angle and g is the acceleration due to gravity while h is the relative take-off height, given by:

$$h = h_{take-off} - h_{landing}\,, \tag{3}$$

with the take-off height $h_{tke-off}$ and landing height $h_{landing}$ (figure 1).

The second option in long-jump study is to take into consideration the influence of air influence. In this case there are toke into consideration both drag and lift forces.

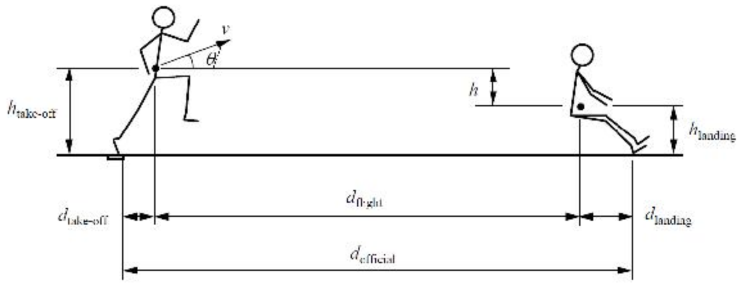

Figure 1: The official distance jumped and its components [6]

In [4] there are presented two pairs motion equations with linear drag and quadratic drag force. In case of linear drag, the equations are given by:

$$\begin{cases} a_x = -\dfrac{c}{m} v_x\,; \\ a_y = -g - \dfrac{c}{m} v_y\,, \end{cases} \tag{4}$$

and in case of quadratic drag force, the motion equations are [4], [7], [8], [2]:

$$\begin{cases} a_x = -k\, v_x \sqrt{v_x^2 + v_y^2}\,; \\ a_y = -g - k\, v_y \sqrt{v_x^2 + v_y^2}\,; \end{cases} \tag{5}$$

where $k = C_D A° /(2m)$ is a constant, C_D is the drag coefficient, A is the cross-sectional area of the athlete in a plane normal to his velocity, ° is the air density, v_x is the velocity on x direction, v_y is the velocity on y direction, a_x is the acceleration on x direction, and a_y represents the acceleration on y direction.

An exact solution for the equation (5) and in [8] it is given an approximated equation of the trajectory as:

$$y(x) = x\left(\frac{v_{x0}}{v_{y0}} + \frac{g}{2kv_{x0}^2}\right) - \frac{g}{4k^2 v_{x0}^2}\left(e^{2kx} - 1\right), \tag{6}$$

where v_{x0} and v_{y0} are the launching velocity of the center of mass at take-off.

3. EXPERIMENTAL SET-UP

The aim of the study was to simulate and compare results based on the concept of mass centre motion during the long jump. There were considered two subjects, members of the Romania National Athletic Team with different jump techniques.

During the tests, done at the Athletics Squad in the Romanian National Sports Complex (Poiana Brasov), there were recorded the mass centre of the athletes and were found the take-off velocities (initial velocities v_{x0} and v_{y0}).

Record were done using a high speed camera (AOS X - PRI) (figure 2) done with a resolution of 800x600 pixels at 500 frames/s. In the mass centre of jumpers there were attached coloured markers (figure 3). The video camera AOS X –PRI was connected to a Laptop being used a specialized soft for recording.

Figure 2: Camera AOS X –PRI and recording data system

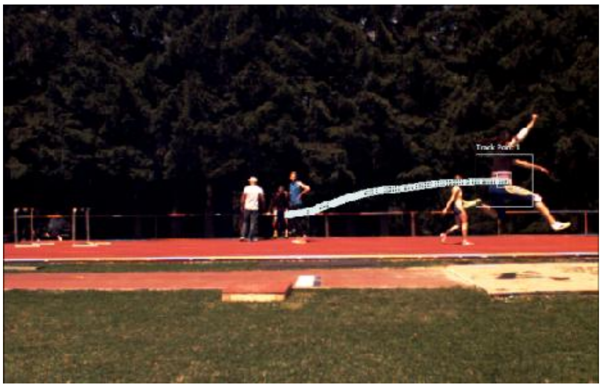

Figure 3: The trajectory of jumper mass centre highlight by markers

The video camera AOS X –PRI was placed on the perpendicular direction on the jumpers at a distance of 5.20 meters from the jump path.

4. RESULTS

Based on relation (6) there were simulated, on Matlab, the trajectory of the mass centre for the two athletes considered in experimental set-up. The used data are presented in Table 1.

Table 1: Data measured – equation (6)

Athlete	Jump	Velocity $v_{x0}\,[m/s]$	Velocity $v_{y0}\,[m/s]$	Take-off velocity $v\,[m/s]$	k	Angle $-[\circ]$	Length [m]	
							official	simulated
RD	1	8.425	2.412	8.763	0.31	15.98	3.91	7.07
	2	6.999	2.421	7.406		19.09	5.17	5.94
	3	7.761	3.026	8.330		21.31	5.03	6.12
	4	7.094	2.962	7.688		22.67	5.26	5.62
GB	1	9.998	2.893	8.954	0.23	22.03	5.84	7.73
	2	8.301	3.357	8.973		23.18	7.07	6.31
	3	8.250	3.530	9.383		22.03	7.20	6.18
	4	8.698	3.518	9.163		19.69	6.98	6.50

The two athletes were denoted by RD and GB. They are male athletes with good results. The tests were done in specific atmospheric conditions for Poiana Brasov and was not took into consideration the wind. The value for the coefficient k was found according with the anatomical characteristics of each athlete (mass, cross-aria) and aerodynamic values corresponding to the air density and drag coefficient C_D.

In figure 4 it is presented the trajectory of the athlete RD and in figure 5 the trajectory of the athlete GB. As it can be seen from table 1 between official and simulated there are differences. A view of differences is presented in figures 6 and 7.

From recorded data and figures 6 and 7 result that the error are in a range of 6.4% and 44.69%, for athlete RD (figure 8), and in a range of -7.38% to 24.45% for the athlete GB (figure 9).

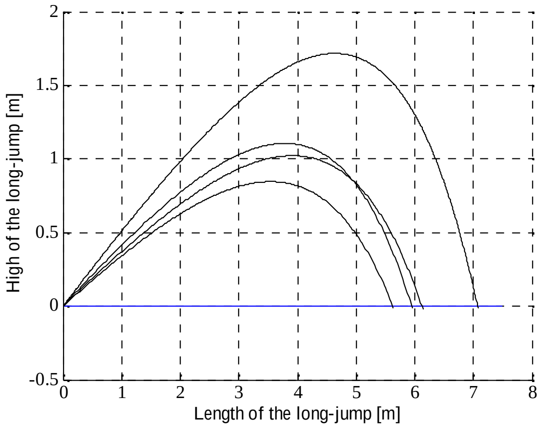

Figure 4: Traiectory of the RD athlete

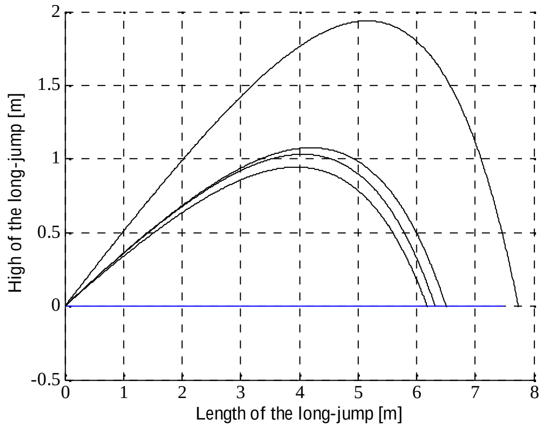

Figure 5: Traiectory of the GB athlete

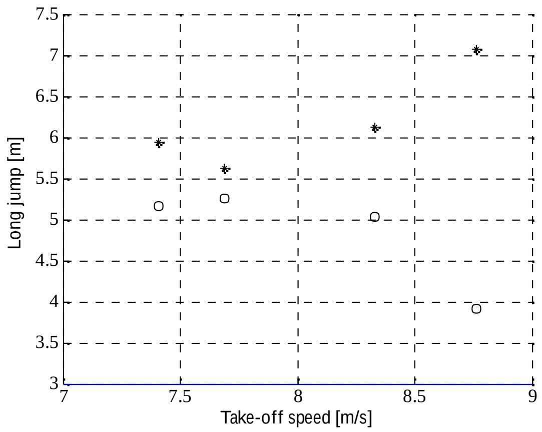

Figure 6: Distribution of jumped length for RD athlete as function of take-off speed: o – official; * - simulated

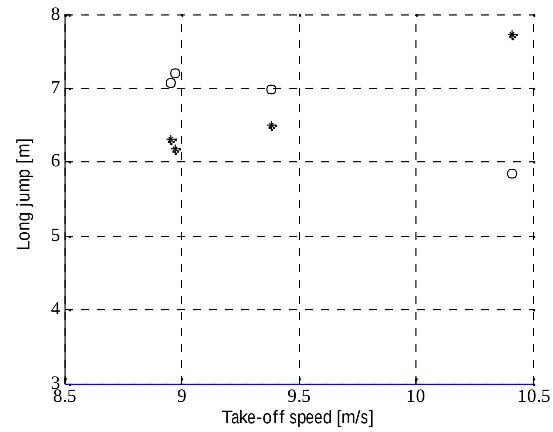

Figure 7: Distribution of jumped length for GB athlete as function of take-off speed: o – official; * - simulated

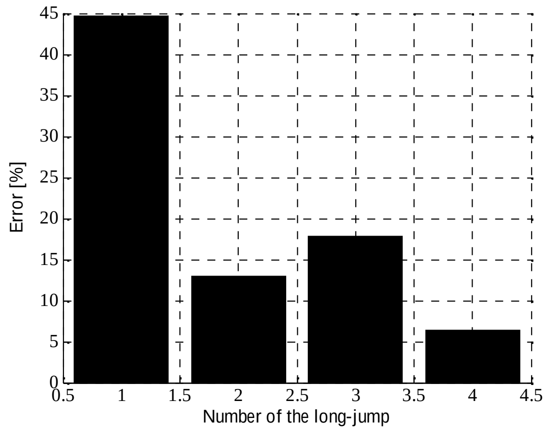

Figure 8: Error distribution of jumped length simulated for RD athlete (eq. 6)

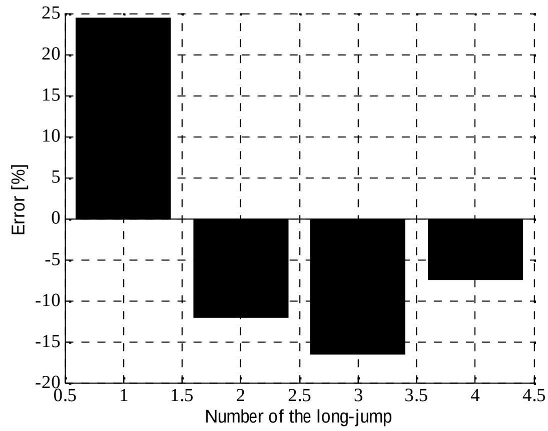

Figure 9: Error distribution of jumped length simulated for GB athlete (eq. 6)

Considering equation (2) for both athletes there were found the following results presented in table 2. Considering the measured data and simulated length based on equation (2) one can see that the errors are in a range of -3.64% to -75.18% , for RD athlete (figure 12), and in range of -12.18% to -64.71%, for GB athlete (figure 13).

Table 2: Data measured - equation (2)

RD	$h\,[m]$	0.2	0.15	0.15	0.25
	$d_{official}$	3.910	5.170	5.030	5.260
	d_{sim}	3.7727	2.9512	3.7512	3.7435
GB	$h\,[m]$	0.25	0.15	0.2	0.25
	$d_{official}$	5.84	7.07	7.20	6.98
	d_{sim}	5.2056	4.2922	4.6346	5.0829

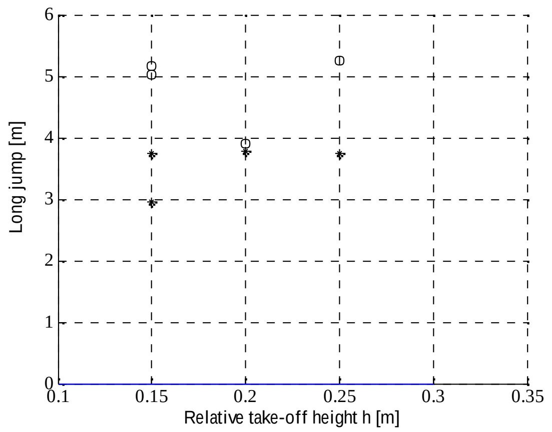

Figure 10: Distribution of jumped length for RD athlete as function of h : o – official; * - simulated

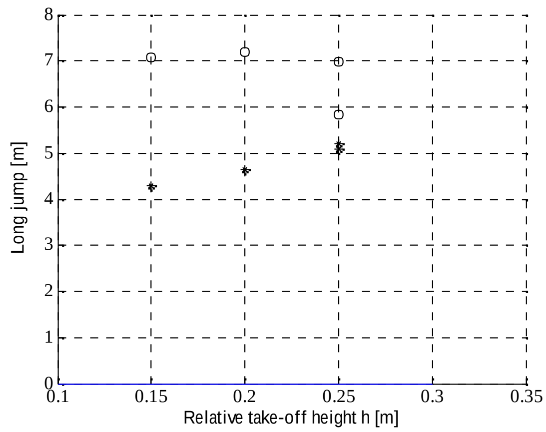

Figure 11: Distribution of jumped length for GB athlete as function of h : o – official; * - simulated

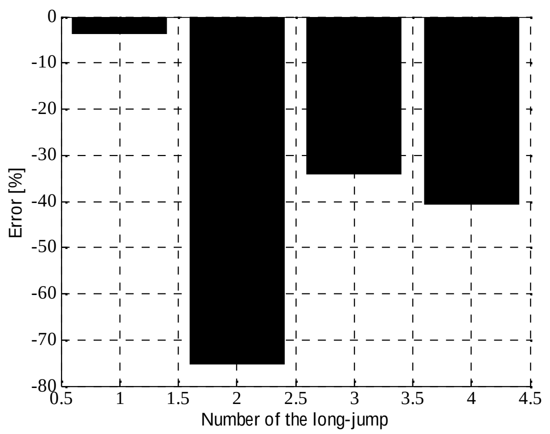

Figure 12: Error distribution of jumped length simulated for RD athlete (eq.2)

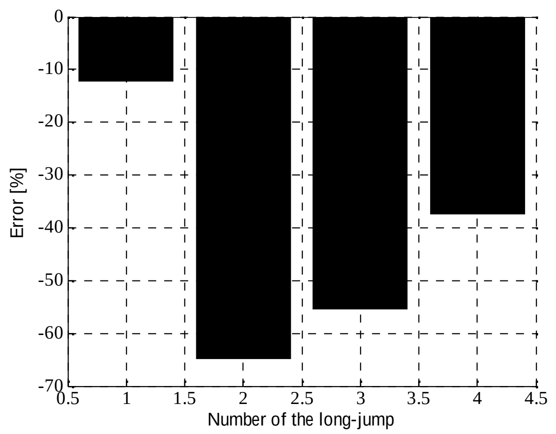

Figure 13: Error distribution of jumped length simulated for GB athlete (eq. 2)

As is seen for both athletes at the second trial de error are very large, practically the recoded data can not be considered relevant in the study

5. CONCLUSIONS

The aim of the present paper was to simulate the long jump of two athlete considering two relations (2) and (6) and measured data.

As it can be seen in the presented simulations based on the above mentioned equations give errors that are very large in case of equation (2).
The simply motion equation without taking into consideration the interaction with the air generates large errors and the obtained results are far from the official length.
In case of the equation (6) it is considered the effect of the air influence and the result are more closed to the real measured data.
In both cases the simulated lengths were larger than the official jumped lengths (figures 8, 9, 12 and 13).
The differences can have few causes as: the athlete is considered through the mass centre not as a multi body model, the results are influenced by the athlete technique and the level of fatigue and warm, there are not took into consideration the inertia moments.
A more complex model can offer better results. This is a subject that can be offered by the equations (5) and it will be studied in further simulations.

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