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Article

Experimental validation of a method for virtual testing of bike settings

Cyrille André[1], Cédric Lemaître[1] and Matthieu Voiry[1,*]

[1] Apeira Technologies, 40 rue Jean Jaurès, 71200 Le Creusot, France

* Correspondence: MV: m.voiry@apeira-technologies.fr

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Abstract: Based on our previous works, we propose a method for virtual testing of bike settings. This allows the biomechanical and aerodynamic properties of a bike setting to be assessed without having to test it in real life. We also perform an experimental validation of the method by comparing measured and simulated values of different indicators: the frontal area, the maximum knee flexion, the maximum knee extension, the hip angle closed and the hip angle open.

Keywords: Optimal positioning, Virtual pose, Aerodynamics, Biomechanics

1. Context

Optimizing rider position is a major challenge in cycling. It's a difficult problem because this optimization must take into account aerodynamics, biomechanics and injury prevention. On one hand, on flat road conditions, aerodynamic drag represents about 80% of the total resistive forces applied to the cyclist. On the other hand, measuring dynamic joint angles provides relevant biomechanical parameters associated with performance optimization and injury prevention [1-3]. Thus, one strategy to approach the optimal position is to optimize aerodynamics under the constraints of keeping joint angles within the limits recommended by the literature. Such a strategy requires testing a large number of positions for which aerodynamics and joint angles have to be evaluated. Different methods have been proposed for measuring aerodynamics [4-5] and joint angles [6]. However, these methods are time-consuming and/or costly and therefore an iterative optimization of the position may be difficult to implement.

In this context, we introduced previously a new computer vision-based method to assess the aerodynamic drag of cyclists [7]. This system also allows the measurement of joint angles during pedalling. In this work we show how our framework can be used to virtually change the bike settings and predict the joint angles and frontal area in this new position. In addition, we experimentally study the accuracy of these predictions.

2. Virtual modification of bike settings

We developed previously a motion capture system based on four inexpensive commercial RGB-D cameras [8]. This system infers both skeletal pose and surface of a moving human body by fitting a template model to depth maps measured by the four sensors. The appearance of the body model is driven by two sets of parameters. The shape parameters describe the body morphology and remain constant for an individual. The pose parameters describe the position of the skeletal joints.

With this framework, we can produce virtual 3D sequence from a measured reference sequence by simply defining new bike settings. First, the shape parameters are left unchanged. Then, some pose parameters are calculated by forcing the body model to be in contact with the pedals, the saddle and the handlebars of the bicycle. Finally, some pose parameters (e.g. elbow and ankle angles) are directly imported from the reference sequence. Figure 1 shows an example of a virtual 3D model obtained with our method. This allows us to simulate a complete pedalling cycle, generate the corresponding 3D models from which we can derive joint angles and frontal area measurements.

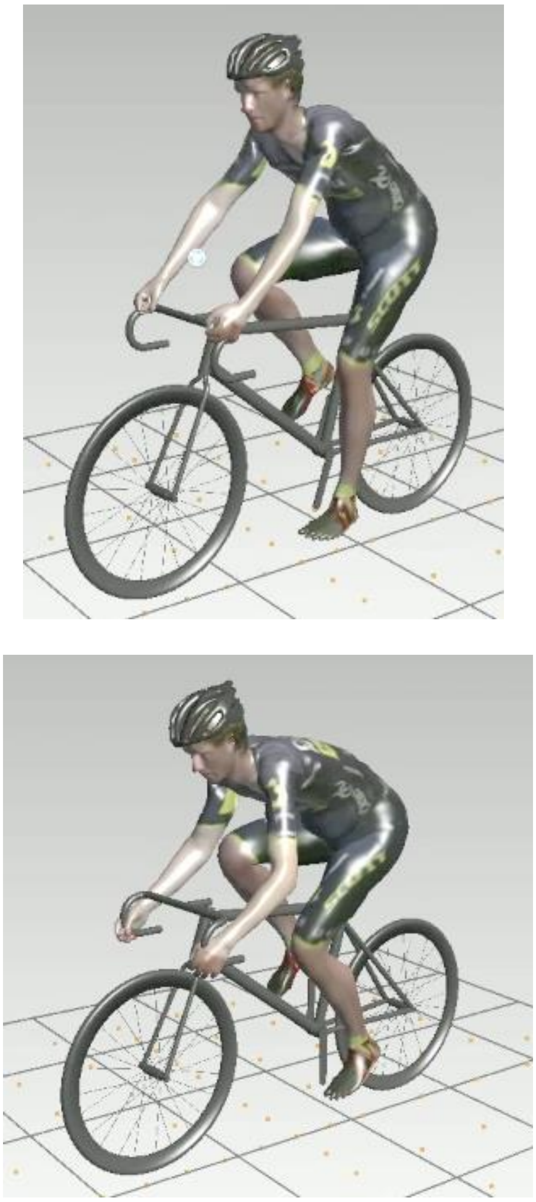


Figure 1. Reference model (top) and model after virtual modification of bike settings (bottom).

3. Materials and Methods

Design—Using the experimental set-up presented previously [7], we collected data from 11 subjects. All are men between 18 and 20 years old who practice sport intensively and cycle at least once a week. We recorded 10-second pedalling sequences for the preferred bike setting and for a number of other settings: by changing the saddle height by +2, +1, -1, -2, -3 centimeters, the handlebar height by -2, -3 centimeters and the handlebar reach by +2, +3 centimeters. Our measuring system provided for each bike setting a set of 3D models describing the pedalling cycle. On the other hand, we used the method described above to generate virtual sets of 3D models corresponding to the same bike settings; the data corresponding to the preferred setting was used as a reference sequence.

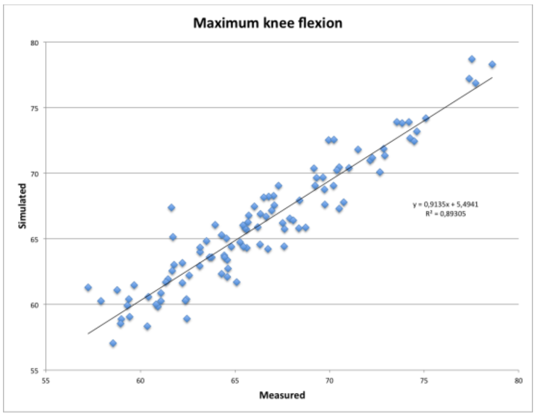
Data processing—Each set of 3D models was processed in order to calculate different indicators: the frontal area, the maximum knee flexion (maximum flexion of the knee joint at any point in the pedal stroke defined by the hip-knee line and the knee-ankle line), the maximum knee extension (maximum extension of the knee joint), the hip angle closed (the most closed angle of the hip joint defined by the knee, hip and shoulder) and the hip angle open (the most open-angle of the hip joint) - these angles were calculated for both legs.

4. Results

We compared the values of indicators obtained on the one hand by direct measurement and on the other hand by simulation (virtual modification of the bike setting).

Figure 2 depicts results for the maximum knee flexion/extension and linear regressions. These linear regressions show proportionalities close to 1 (1,065 and 0,914) with good coefficients of determination (0,893 and 0,782).

Figure 3 depicts results for the hip angle open/closed and linear regressions. These linear regressions show proportionalities close to 1 (0,965 and 0,821) with good/correct coefficients of determination (0,833 and 0,513).



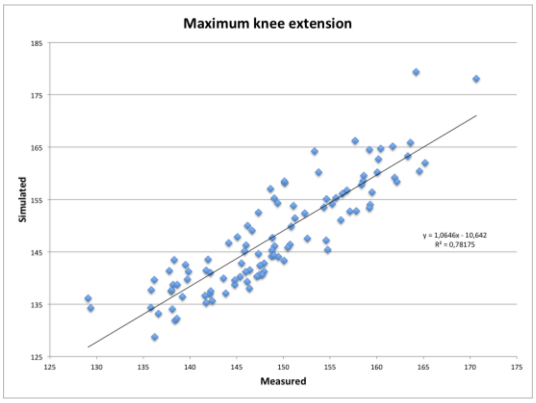
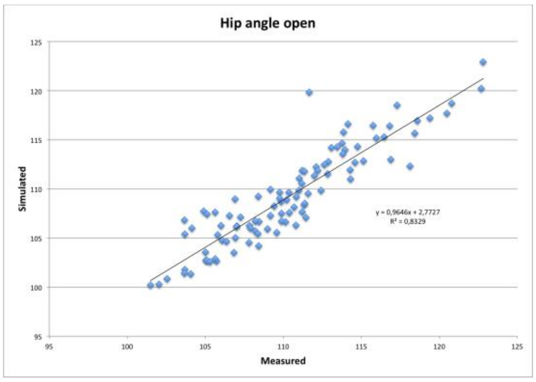


Figure 2. Measured VS simulated maximum knee flexion (top) and extension (bottom).



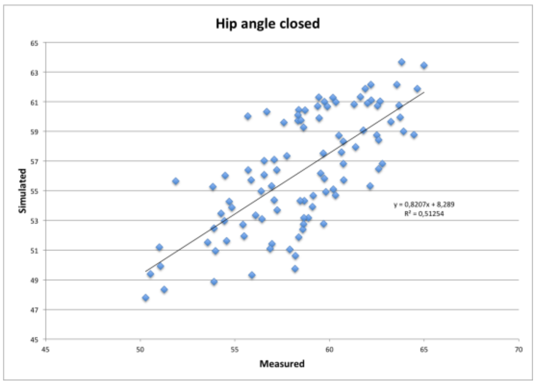


Figure 3. Measured VS simulated hip angle open (top) and closed (bottom).

Figure 4 depicts results for the frontal area and linear regression. This linear regression shows proportionality close to 1 (0,918) with a good coefficient of determination (0,923).

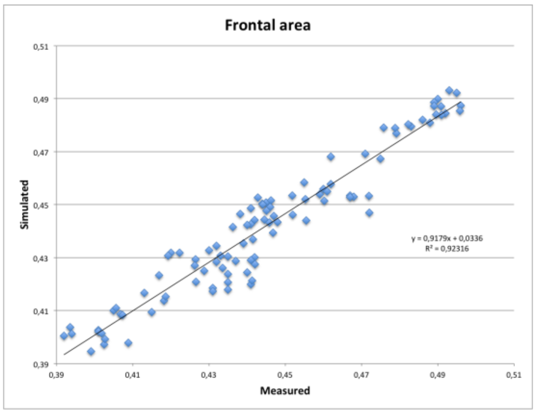


Figure 4. Measured VS simulated frontal area.

5. Discussion

These results prove that it is possible to assess the range of variation of the knee and hip joint angles for a given bike setting without having to test that setting in real conditions. This assessment is approximate but still useful as the recommended joint angular ranges are quite wide [9]. Moreover, we show that it is also possible to robustly assess the frontal area. These indicators are the most important for evaluating the biomechanical and aerodynamic properties of a bike setting [10-11], thus the proposed technique can be used to virtually test the suitability of a new bicycle setting.

5. Practical Applications.

In this work we perform an experimental validation of a new method to virtually test bike settings. We showed that there is a good agreement between indicators of the biomechanical and aerodynamic properties of bike setting measured directly or virtually. However, we do not believe that this virtual testing method can replace real testing. But it can be used to quickly and inexpensively explore the bike setting space as part of an iterative process to optimize a rider's position and thus to limit the number of set-ups to be tested in real life.

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Conflicts of Interest: The authors declare no conflict of interest.

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