CONTOUR ANALYSIS, A NOVEL APPROACH IN MOVEMENT SCIENCE

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Contour Analysis is a novel way for analyzing movements, which is specifically developed for daily use in high performance sports. The Contour Analysis is part of an automatic video capture and playback system, the CoachCockPit. Parameters like position, velocity and average body angle are obtained and also less straightforward parameters as step length or step frequency or 3D discus trajectory and speed can be investigated with Contour Analysis. The system is designed to operate fully automatic with a minimum of user input. Performance parameters obtained from the Contour Analysis can be used for direct feedback and to monitor progress over longer periods of time. To illustrate this several examples in different sports are discussed. The CoachCockPit is developed with primarily the coach perspective in mind: it does not interfere with daily training.

KEYWORDS: Markerless Movement Analysis, biomechanics, Performance Analysis, Feedback monitoring performance

INTRODUCTION: In elite sports feedback is used more and more to evaluate performance and optimize training programs to the individual needs of the elite athlete (Wm. A. Sands & Stone, 2005). In endurance sports feedback on the performance is already common practice: 100 m times, split times, heart rate, blood lactate e.g. are relatively easy to measure on a regular basis. More complex biomechanical parameters however are not easily measured especially not on a regular basis. Precise biomechanical analysis is often done with a marker-based technique taking up quite a lot of time and support staff. Moreover, it does interfere with training. It can give interesting insides to the biomechanics of the movement but only a few times per year and the outcome comes usually too late to use it directly during the training.
For ‘direct’ feedback during training and to monitor progress over a training, a training period or several years, objective measures of performance should ideally be measured on a regular (daily or weekly) basis (Hopkins, 1998). For technical sports like gymnastics or a discus throw evaluation of the performance on a regular basis would support an optimal training process. This paper discusses a novel system that does just this.
At the VU University in Amsterdam a novel video based analysis system has been developed to measure performance automatically and on a regular basis during daily training practice. The CoachCockPit does not interfere with training or impede the performance since no markers or sensors are attached to the athlete. The CoachCockPit is designed with the coach and athlete as primary user in mind. The user input, once setup, is minimal since capture and playback are to a large extent automated. Small-predefined sequences of the movement are captured and stored. Typically just the jump, sprint or start. This is done to reduce the amount of data and for easy playback because only the desired movement is captured. Synchronization between trials is usually good, making visual comparison of different trails easy. Furthermore, this setup provides automatic analysis capabilities and thus enables ‘direct’ feedback during training within seconds (typically 15-30 sec) after the performance.
Contour analysis can be used in different ways. After a general description of the system the different ways to utilize the system together with examples of different sports will be discussed.

METHODS: The process of analyzing a movement with the CoachCockPit generally consists of 5 steps: automatic capture of the movement, displaying the raw footage for visual feedback, analysis of the footage producing raw data and the specific analysis depending on the movement and presentation of the results.

In a basic setup one camera is positioned perpendicular to the plane of motion. More camera's can be added (up to 3) from other angles, like a frontal camera depending on the movement under investigation and the wishes of the coach. Calibration of the video data is necessary if outcomes in the metric system are needed or if measurements of different setups are to be compared.
The automatic analysis produces raw data like center of mass, general direction of body, elongation (over 15 basic parameters) and the contour of the body. The parameters are all taken from the footage and therefore represent an optical representation of a biomechanical quantity. For the use in 'direct' feedback and monitoring performance they can be used as similar quantities and with sufficient accuracy. Standard procedures used for marker kinematic data like filtering or fitting can be applied. Using basic physical/ biomechanical laws accuracy can be improved. After the Contour Analysis the raw data is used to calculate performance parameters. For instance jump height from the center of mass trajectory or number of full rotations from the general body angle.
Analog data from force plates or other (wired) instruments can be collected synchronously with the footage. Since footage is always available it is always possible to annotate the data in a later stadium, in contrast to many other data collection systems. Part of the annotation can be automated as well. Successful attempts have been made to automatically evaluate the type of vault performed in gymnastics.

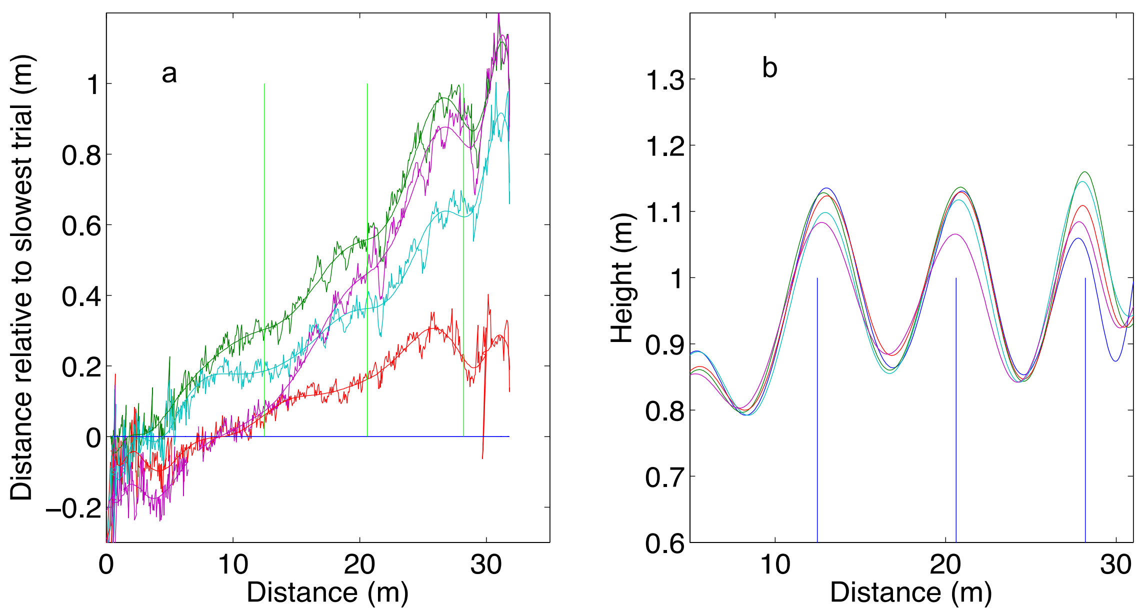

Figure 1a: Relative position of four hurdle runs compared to the slowest overall (time at 30 m) attempt. Raw data and fitted curve are shown; standard deviation between 0.04-0.06 m. b: Center of mass position data of four hurdle attempts (fitted data). The vertical lines indicate the position of the hurdles.

The calculated performance parameters can be used directly during a training session as feedback and to monitor progress during a training period or year. In the remainder of this paper 2 examples from different sports are explored to show the possible ways to use the CoachCockPit. The CoachCockPit is originally designed for analyzing performance in gymnastics and currently being tested in several other sports, like athletics (sprint, hurdling, long jump, pole vault and discus throwing), speed skating and swimming. In the shown examples only one camera was used, but by using several camera's a semi 3D analysis can be performed.

HURDLE: A case study on hurdling was performed to investigate the possibilities of video analysis on a larger spatial volume, in this case approx. 30 m and to study if horizontal and vertical displacement and velocities over the hurdles were measurable with the system.

Comparing the relative positions of the athlete during four different hurdling attempts of one athlete revealed quite large differences (**Error! Reference source not found.**a). One remarkable attempt is the purple line, although slower before the first hurdle, it becomes the fastest attempt after the 2nd hurdle. In **Error! Reference source not found.**b the center of mass position data of the purple attempt suggests why this attempt is faster: the center of mass passes lowest over the hurdles.

VAULT: Earlier work on vaulting showed that vault height is directly correlated to the score judges give during competition, that is, a vault performed higher in the air is likely to have a higher score (Eb, Ackermann, Koning, & Coolen, 2013; Eb et al., 2010). These findings can be used during daily training. The CoachCockPit is capable of measuring and providing an analysis for every vault performed within ~20 sec. providing the opportunity to closely monitor performance.

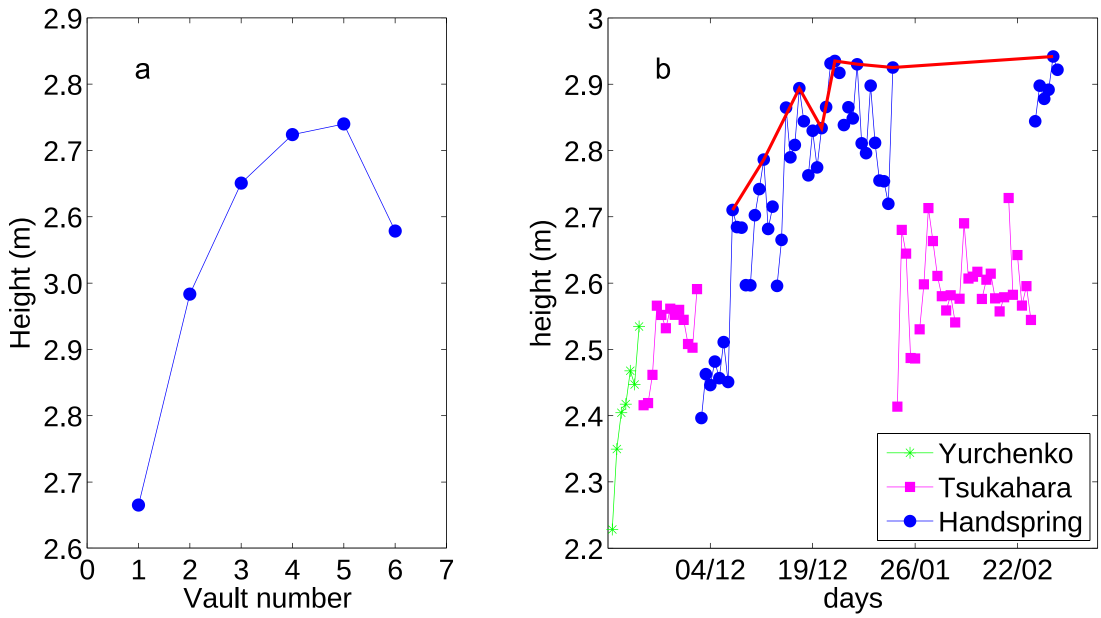

Figure 2a: Vault height of one athlete during one training session. b: Vault height is monitored over an extended period of time for one athlete. One line connecting the dots represents one training session. The different colors are different types of vault. The red line connects the highest vaults per training.

Error! Reference source not found.a shows a typical example of the vault height build up during a training session. In this case the gymnast has performed six vaults, starting with one or two low warm-up vaults and then subsequently three performance vaults. The last attempt is quite a bit lower again, the gymnast stopped his training either because he reached the number prescribed attempts or he felt that his performance declined. The decrease in performance shows that he was probably fatigued and was not able to make an optimal push-off. However, this interpretation will differ for each individual. **Error! Reference source not found.**b shows the vault heights for several consecutive training sessions. The red line connecting the highest vaults per training shows a clear pattern: the athlete attempts a handspring double somersault (blue dots) and the maximum height gradually increases over several training sessions, indicating that desired result is not jet reached. When the athlete reaches a maximum height of approx. 2.9 m the increase stops. The attempts are now successful, that is, he lands on his feet. Data from the WC 2010 show that this height is the lower bound during competition.

ACCURACY: In general the Accuracy of Contour Analysis is not easily given. In absolute sense it may not be very accurate, but depending on the specific movement studied, whether trials of one individual athlete or more athletes and the camera has a fixed position the accuracy can be quite high. In the Hurdle example the raw data is presented together with an appropriate fit, the standard deviation is in the order of 5 cm. In the same experiments different measurement techniques, Time gates (PhotoGate, BROWER Timing Systems Inc., Draper, USA), Radar gun (Stalker Pro, Applied Concepts, Plano, Texas) and Contour Analysis were compared and will be discussed in more detail in a paper in preparation. The results of one hurdle attempt (Male age 18 years, 71.5 kg, height 1.75 m) are presented in **3** and show a good comparison. The maximum difference between radar gun and Contour Analysis differ less then 0.6 m/s in the first 5 m and for the intervals less then 0.2 m/s for 5 trials. Time gate averages do not compare as good as the other two. In the first 10 m this is due to the averaging over 5 m of 2 time values. The 4th and 6th data point are too high, probably because the gates are placed relatively close to hurdle. The lifting the foreleg triggers the gate too soon.

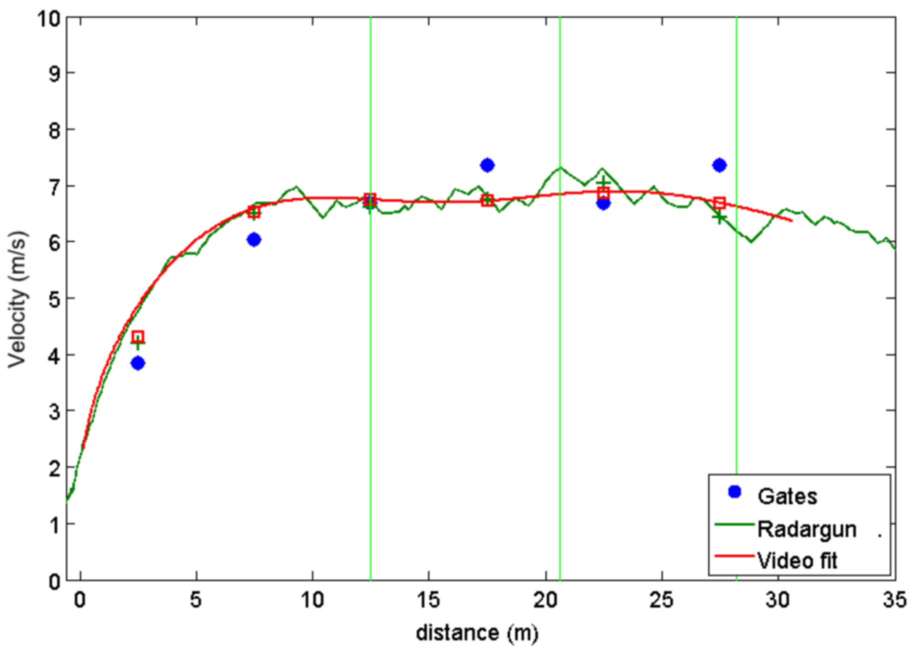

Figure 3 Velocity profile of one hurdle attempt. 3 measurements are taken simultaneously showing a good comparison. The Time gate values are averages over 5 m intervals. Radar gun is not treated. Contour Analysis data is fitted with a 9th order polynomial. The squares and crosses indicate the average over the same intervals.

CONCLUSION: The Contour Analysis is a versatile movement performance analysis system that can be utilized in many different ways. Performance parameters can be obtained quickly and on a regular basis for ‘direct’ feedback and to monitor performance over a longer period of time. By far not all possibilities are explored. The CoachCockPit is developed with primarily the coach and athlete perspective in mind: it does not interfere with daily training or impede the athlete.

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