3D at 2000 Hz at 300 km/h

HIGH-SPEED VIDEO ANALYSIS FOR MOTORSPORT.

3D evaluation of high-speed recordings for analyses on motorcycle chassis components on the racetrack and in everyday use.

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3D evaluation of high-speed videos is well known, for example in safety analysis and from motion analysis in sports. But high-speed recordings can also provide valuable information in motorsport, particularly motorcycle racing. Extremely short exposure times and high frame rates on modern high-speed cameras not only deliver impressive sequences of images in super slow motion, they also allow objective analysis based on measured values on the vehicle and the chassis components.

3D analysis with camera

3D points on a motorcycle can be quickly and easily identified with a stereo image high-speed camera system. Camera speeds of 2000 frames per second (fps) allow detailed chassis analysis in extreme situations. Lean angle, speed and acceleration can also be directly linked to wheel revolutions, spring rates and even the rider's posture on the bike. 3D analysis is frequently capable of identifying unexpected movement that would be very difficult, perhaps impossible, to detect using sensors. Flex of the entire chassis can even be compared with the original design.

With up to 200 horsepower and a weight below 200 kg, so-called superbikes can accelerate from 0 to 100 km/h in less than 3 s and have a top speed of up to 300 km/h. An increasing number of private riders are thus using their sports motorcycle not only on the road, but also for training on a racetrack. With rebound and compression damping as well as spring preload on the forks and on the rear strut, the motorcycle can be tailored to the rider's weight and the track in order to achieve high cornering speeds, maximum acceleration and short braking distances.

While driver safety training is primarily concerned with preventing accidents

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on the road by safe emergency braking and hazard avoidance, when it comes to riding on a racetrack, a fast lap is the top priority. Both areas benefit from the rider's ability to optimally slow down the bike.

Measurement strategy

A small number of measurement markers attached to the bike at clearly visible points allow a complete analysis of the interaction between the individual chassis components.

On a racetrack, one typically accelerates on the straights and brakes as late and as hard as possible just before entering a corner. **Figure 1** shows the braking at the end of the back straights at the Oschersleben Motopark (Germany), from speeds of well over 200 km/h down to around 120 km/h.

1 **Braking from a high speed**

The recording enables the exact braking point and the maximum deceleration to be determined as well as the spring travel on the forks and the position of the rear of the bike to be measured. The remaining spring travel on the front wheel can also be measured and must remain in control without bottoming out. The high resolution of a high-speed camera together with high sensitivity and low noise enables the initial response of the motorbike, which is critical for a short braking distance. The build-up of braking rate can also be measured.

Maximum deceleration allows late braking points and therefore longer acceleration periods. For example, imagine two riders, A and B, both of whom are at a speed of 200 km/h at the braking point and which needs to be reduced to 100 km/h at the end of braking. Rider A requires 0.3 s for maximum braking to be achieved, rider B just 0.1 s. This means that rider B can start braking 10 m later, thus gaining a crucial lead at the entrance to the corner.

In the acceleration phase at the exit from the corner, as can be seen in **Figure 2**, the performance of the rear end is crucial. Here, a 3D analysis allows the lean and acceleration to be determined, in conjunction with an analysis of the suspension and damping on the rear of the bike. ▶

2 Accelerating out of a corner

A Braking distances (full braking) for different rider reaction times, specified for 50 and 100 km/h. Also shown are the final speeds of riders with slower reactions, measured at the end of the braking distance of the rider with the fastest reaction time

Time [s]	V_s [km/h]	Braking distance [m]	V_e [km/h]
0.3	50	10.7	0
0.5	50	12.3	21
1.0	50	15.4	37
0.3	100	40.8	0
0.5	100	44.0	31
1.0	100	50.6	52

Applications away from the racetrack

The same technology can also help participants in driver safety training to learn about emergency braking. Unlike in a car, the braking distance on a motorbike depends hugely on the individual abilities of the rider. Training and practice on a closed track are essential for achieving maximum deceleration when braking. The reason for this is that the front wheel in particular should not lock, as this almost inevitably leads to a crash. However, fear of crashing due to a locked front wheel often hinders the rider from rapidly reaching full braking potential, which is essential in achieving the shortest possible braking distance.

Table A illustrates the relationship between three different times a rider requires to reach maximum braking and the resulting braking distances for full braking, both from 50 km/h and from 100 km/h (a linearly increasing deceleration of 0 to 10 m/s^2 is assumed). From 50 km/h the braking distance is extended by up to 5 m, from 100 km/h by up to 10 m. Even more revealing are the speeds V_e with which the 'slower' riders are still moving after 10.7 or 40.8 m (at which points the 'fast' reacting rider is already at a standstill).

3D analysis with a single camera

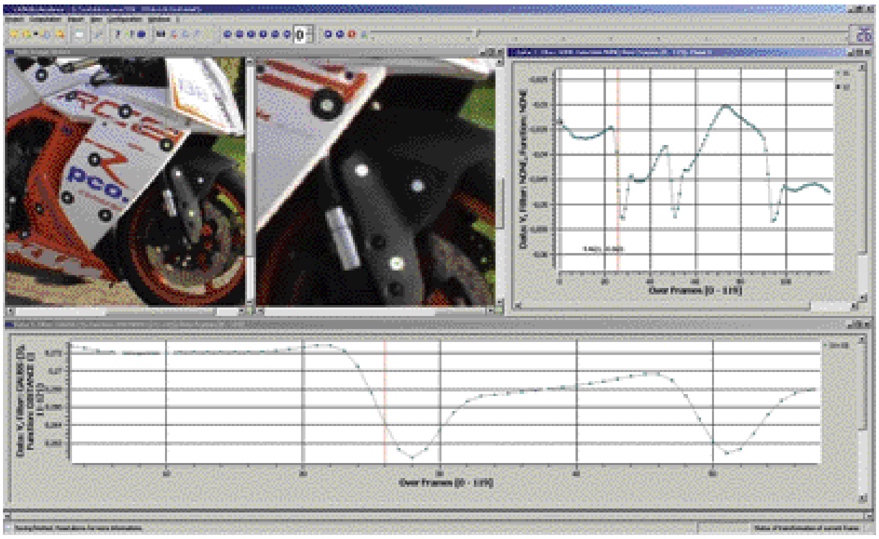
A 3D video analysis system such as the›SOLVing3d.titan‹ system is made up of a low-noise, high-speed camera system (the ›pco.dimax‹ in this case) and a stereo mirror attachment (**Figure 3**). The high resolution sensor on the pco.dimax has 2016x2016 pixels and the stereo mirror attachment used in the S3D.titan system has a fixed stereo basis of 300 mm and slightly convergent acquisition axes.

The two stereo images are normally mapped to the central area of the sensor (2016x1008) and thus resulting in two image sequences during the recording – each with 1008x1008 pixels and slightly different angles of view. The system provides an exceptionally image quality and resolution of the 3D stereo film, in color and at a frame rate of 2128 fps.

The system is calibrated in the same way as a normal stereo camera system. After appropriate conversion, two time-synchronous image sequences from the virtual stereo camera are obtained, which can be evaluated in 3D. This kind of system is very compact, robust and comparatively easy to use. A disadvantage of the titan system compared to a stereo measurement system with two cameras is the reduced flexibility in the choice of location due to the fixed geometry of the mirror attachment. The advantages are the very robust operation and the elimination of synchronization errors and differently exposed stereo sequences.

When analyzing the recordings, the accompanying software provides comprehensive functions for calculating and display-

3 The ›SOLVing3D.titan‹ 3D video analysis system



4 **Software interface for the ›SOLVing3D.titan‹ system**

ing the measured results (**Figure 4**). This enables analysis of parameters such as position, speed, acceleration, orientation and trajectory progressions to be determined quickly. The software supports evaluation with menu-based evaluation processes.

The software can also be used to geometrically correct the image sequences so that they can be viewed stereoscopically. The resulting 3D impression often makes it easier to interpret the measured values. For close-up applications the S3D. titan system achieves accuracies of 0.3 mm.

A further advantage of the measurement system over the individual measurement sensors mentioned above (which would have to be attached to the motorbike along with the corresponding data capture equipment), is that only low-cost point markers have to be attached to the bike or to the rider. Only one set of measurement equipment is required and can thus be used directly for multiple bikes. This enables comparative analyses between different riders and bikes to be carried out. This makes the system ideal for analysis within small groups – including driver safety training.

Summary

Using high-speed 3D video analysis in driver safety and race-track training provides valuable information to improve motorbikes and rider behavior. This kind of measurement system can also be used for other applications such as crash testing, motion analysis in various branches of sport and much more.

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