ACCURACY OF THE SOFTWARE GENLOCK WITH DIGITAL CAMCORDERS

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INTRODUCTION: Recently, digital camcorders have gained popularity as a viable means of recording movements in video motion analysis, mainly due to the ease of use and reasonably high image resolution. Digital camcorders, however, suffer from a major drawback, lack of the hardware genlock capability. Camcorders thus operate independently from each other and introduce time offsets among themselves. These time offsets in turn violate the requirement of simultaneous observations from multiple cameras in the 3-D analysis, producing erroneous real-life coordinates of the markers. This is especially true in fast motions, in which a small time offset can be translated into a large spatial error, and the time offsets must be corrected before the 3-D reconstruction. The genlock (synchronization) of the cameras can be potentially achieved by a software-based strategy, the software genlock. The purpose of this study was to investigate the accuracy of the software genlock using digital camcorders.

METHODS: A software genlock algorithm was developed based on a non-linear camera calibration model with the optical error correction capability. The overall mean square error (MSE) involved in the reconstruction of the real-life marker coordinates was assessed and a series of systematic adjustments of the time offsets were performed through minimization of the MSE. The resolution of the time offset adjustment was one-hundredth of one field time (FT = 1/60 s) and the range of adjustment was within 1 FT of the nominal sync event frame. Ten golf drives performed by a recreational golfer were recorded by four digital camcorders (Panasonic DVC-15) with timing lights used to register a common sync event in each camera view. Three reflective markers were attached to the distal part of the shaft, neck (D), 20 cm from the neck (M), and 40 cm from the neck (P), and the MSE minimization was performed based on different marker combinations: three markers (D-M-P), two markers (D-M, D-P, or M-P), and one marker (D, M, or P). A special marker-camera condition was also used, in which marker D was digitized only in cameras 1 and 2, marker M was digitized only in cameras 2 and 3, and marker P was digitized only in cameras 3 and 4. To assess the accuracy of the software-based time adjustments, the actual time offsets were measured from the video signals and compared with the results of the software genlock. For this, the video signals were fed to a data acquisition system at a sampling rate of 10,000 Hz and the actual time offsets among the camcorders were obtained from the vertical blanking pulses with a time resolution of 0.1 ms.

RESULTS AND DISCUSSION: The overall mean time offset adjustment error based on all three markers (D-M-P) was 0.008 ± 0.003 FT or approximately 0.13 ms on the average. The standard error (SE) in the reconstructed real-life coordinates decreased by 92% as a result. The mean adjustment error of the two marker combinations were 0.010 ± 0.005 FT (D-M), 0.011 ± 0.006 FT (D-P), and 0.010 ± 0.003 FT (M-P), respectively (0.17 to 0.19 ms). The SE decreased by 91 to 92% in the two-marker combinations. Single marker conditions generated mean time offset adjustment errors of 0.015 ± 0.007 FT (D), 0.009 ± 0.003 FT (M), and 0.013 ± 0.005 FT (P), respectively (0.15 to 0.25 ms). The SE decreased by 91% as a result of the time offset adjustments. The mean time adjustment error of the special camera-marker condition was 0.019 ± 0.009 FT, or 0.31 ms. There observed was a tendency that the time offset adjustment error increased as the number of markers used in the MSE minimization decreased. None the less, all the marker-camera conditions adjusted the time offsets of the cameras fairly accurately (< 0.02 FT or 0.31 ms on the average). It was concluded from the findings that the software genlock algorithm demonstrated fairly accurate time offset adjustments with three reflective markers fixed on the shaft of the driver in golf drives.