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Automated workflow for 4D scanning cyclists in motion

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1 Abstract

Recent advances in human body modeling have enabled high-resolution reconstruction of articulating subjects in motion. MOVE4D (Instituto de Biomecánica de Valencia) demonstrate the capability to generate watertight 3D meshes of moving humans. However, when a subject interacts with an object—as in cycling—conventional homologous registration approaches fail to produce accurate watertight models due to geometric interference between the body and equipment (Van Gastel & Verwulgen, 2022). This limitation has significantly constrained the study of object-assisted movement and dynamic aerodynamics.

In this study, we present a fully automated 4D scanning workflow specifically designed to address this challenge for cyclists in motion. The system captures high-resolution, time-resolved point clouds (±1 mm, up to 178 Hz) over complete pedal cycles and synchronizes them with multiple external force sensors. The principal advancement is a dedicated pointcloud processing pipeline that isolates the cyclist from the bicycle without requiring intrusive physical modifications or restrictive scanning conditions.

The processing workflow comprises four main steps: (1) detection of the bicycle's position and orientation using three colored reference markers; (2) alignment and insertion of a CAD-

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generated bicycle model into the captured point-cloud scene; (3) removal of all points within a defined proximity of the virtual bicycle model; and (4) cluster-based filtering to retain only the largest remaining geometry, corresponding to the human subject. The resulting clean 4D point clouds are subsequently converted into watertight models, eliminating geometric interference between body and equipment while preserving temporal consistency across frames. Synchronization with pedal and saddle force measurements enables precise temporal coupling between external loading and body surface kinematics.

The developed workflow transforms dynamic cyclist reconstruction from a constrained experimental setup into a scalable, repeatable methodology, enabling rapid generation of watertight, force-synchronized 4D cyclist models for quantitative biomechanical analysis (De Rosario et al., 2023). The resulting scans can be exported to widely supported formats (e.g., .stl, .obj), ensuring interoperability across analysis and simulation software. This technological foundation enables applications in bike fitting, movement stability assessment, fatigue monitoring, equipment and garment development (Yang et al., 2022), and time-resolved CFD simulations of cyclist instability (Winter et al., 2025). Furthermore, the workflow is extendable to other forms of object-assisted human movement.

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