Topological and Semantic Characterization of Moving Point Clouds for Technical Gesture Learning

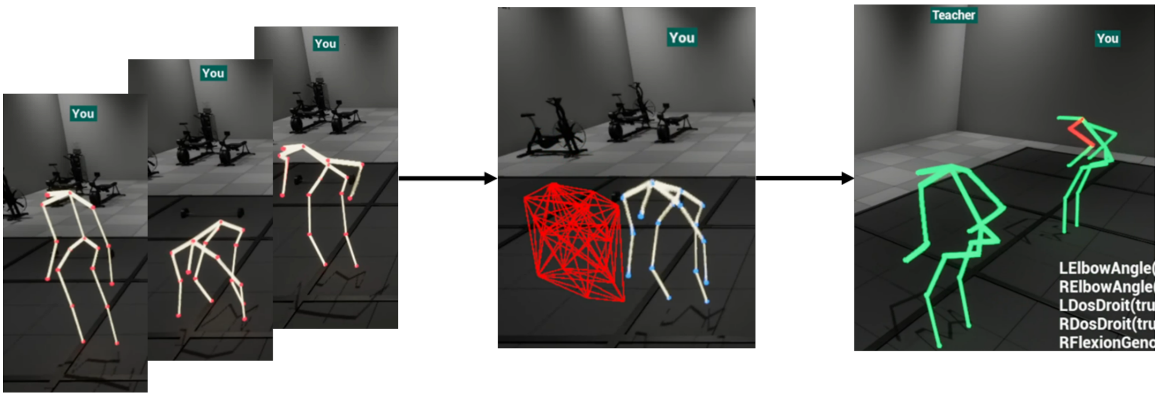

Figure 1: The three components of a digital environment for gesture learning: gesture capture, gesture analysis, and feedback that help the learner to improve.

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Keywords

Topological Analysis, Motion Capture, Point Clouds, Computer Graphics

Context

Many disciplines rely on the performance of *technical* gestures, that is, gestures that require expertise and are acquired through learning. A gesture involves a motor component, as well as functional (its objective) and structural aspects (the learner's knowledge and the context of the learning situation) [3]. Learning such gestures often requires the intervention of an instructor, whose role is to observe and guide the learner. However, this raises several difficulties: an instructor cannot effectively supervise multiple learners simultaneously, and is not always available. As a result, depending on the discipline, some instructors provide alternative learning resources such as videos to partially address this issue or complement their teaching approaches. However, videos suffer from limitations related to depth perception and fixed camera viewpoints. Another approach consists in designing and using virtual environments in which an anthropomorphic 3D avatar demonstrates the gesture. Learners can then control the avatar's animation and observe it from any viewpoint. Automatic gesture assessment functions can also be implemented based on gesture descriptors [1]. The goal is thus to enable instructors to design exercises that learners can perform at any time, with feedback adapted to their performance [2, 5]. Nevertheless, these virtual environments dedicated to gesture learning remain limited, as they are most often designed for a specific discipline and are difficult to reuse, requiring significant engineering efforts for each new discipline or to adapt them to an instructor's specific needs. Part of this limitation stems from the fact that gesture analysis relies directly on the instructor's expertise, which is not always easy to translate into descriptors. This is further compounded by variations in morphology.

Objectifs de la thèse

A gesture is generally represented as a labeled point cloud evolving over time. Topological data analysis [4] is a well-established approach for studying this type of data and can provide descriptors that are independent of the notion of distance between points, thereby addressing issues related in particular to morphology. However, their added value compared to classical descriptors (geometric, kinematic, or dynamic) has yet to be demonstrated, as has their expressiveness for human learning.

The objective of this thesis is to explore the relevance of an analysis based on algebraic topology in the context of gesture learning in virtual environments. To this end, the thesis work will be structured around four milestones: (1) selecting a set of gestures and identifying, for each of them, the observation criteria used by experts; (2) building a dataset, labeled by an expert, comprising gestures performed using motion capture tools (marker-based in a first approach). This includes becoming familiar with the tool, data acquisition, and data cleaning using the functionalities of the proprietary motion capture software Qualisys Track Manager; (3) implementing a configurable analysis pipeline, in which it is possible to select a set of classical and topological descriptors, taking as input a gesture represented as a labeled point cloud evolving over time, and producing an *analysis report*, the format of which remains to be defined; (4) conducting a study on the relevance of the algebraic topology–based approach compared to an approach based on classical descriptors.

Required skills

- Master's degree (or equivalent) in computer science, signal processing, or a related field;
- Experience or expertise related to gestures (dance, martial arts, weight training, etc.) is a plus;
- Strong interest in research and computer graphics (rendering, modeling, analysis);
- Appreciation for fundamental disciplines (mathematics, algebraic topology, etc.);
- Programming skills, in Python or C++. Familiarity with 3D modeling software or game engines is an asset.

Other Information

- Location: XLIM Laboratory, Futuroscope site, Poitiers; Fra,ce;
- Start date: October 2026, flexible;

To apply for this position, please send a copy of your CV along with your academic transcripts to the contact addresses indicated above.

Bibliographie

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