Analysis of Percussion Grip for Physically Based Character Animation

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Abstract

This paper presents the analysis of percussion technique for the simulation of virtual timpani playing situations. The analysis has been processed for two subjects performing with two types of grips (French and German), yielding to the extraction of percussion technique parameters from a motion capture database. These parameters are shown to be necessary for specifying the control and extending the expressivity of the simulation process.

1 Introduction

The present contribution aims at combining the assets of both the dynamic control of virtual characters and the analysis of percussion instrumental gestures, for synthesizing novel physically responsive and sounding instrumental situations. The physical simulation is indeed of great importance for taking into account the physical parameters of the strike (tension, forces) that influence the dynamics of the gesture and the produced sound, while the analysis of percussion grips gives a level of control and different modes of playing to the virtual character.

Either for the physical simulation or the analysis parts, the interest of using motion capture data appears crucial and twofold. Firstly, it provides realistic examples of the human motion under study for driving the virtual character simulation. Physically-based character animation techniques provide a solution to the limited reuse of motion capture data (due to the uniqueness of the capture conditions), and results in synthesizing adaptative behaviors towards environment changes through the simulation of dynamic laws. Secondly, motion capture data allow the specification of the virtual character control by understanding the body characteristics and expressive components that are at stake during the motion. Moreover, the possible alteration of the original motion by the simulation process emphasizes the importance of a comprehensive and useable analysis of the original motion.

This paper presents the extraction of percussion grip parameters that can be used as gesture inputs for the dynamic control of virtual characters performing different technical percussion styles. It is organized as follows. Section 2 reviews previous work about physically-based character animation using motion capture data, style-based computer animation and the analysis of instrumental gestures. Section 3 introduces the overall context and the method used for extracting parameters that characterize percussion grips. The grip influence, in terms of end-point trajectories and angular constraints, is presented in section 4. Section 5 discusses the benefit of such parameters for our synthesis framework. Eventually, section 6 concludes with further perspectives.

2 Previous Work

Data-driven computer animation techniques have widely been studied in the past few years, taking advantage of the increasing availability of quantitative representations of the human motion thanks to the proliferation of acquisition systems.

Music-related contributions for virtual character animation often use a sound-driven approach, such as MIDI-driven [7] or performance-driven [15]. However, these finally prove a lack in taking into account the dynamic aspect of instrumental gestures.

The combination of a motion capture database and physically-based methods yields to frameworks that are well-suited for modeling human-like interactive bodies, since the capture of real movements and the simulation of dynamic laws intrinsically provide physically realistic and adaptative results. The use of physical models for dealing with motion capture data has been involved in motion editing, retargetting and generating transitions between motion clips ([11] [1]). Hybrid methods have also been explored, composing data-driven kinematic and dynamic controllers ([6] [14] [18]), based on the design of PD controllers ([8] [17]) which is also the approach of our work [3].

Regarding stylistic aspects of virtual character animation, previous works concentrate its efforts on extracting and generating expressive motion from motion capture data, and proposes methods based on signal processing ([4] [2]), statistical models ([16] [13]), or the optimization of physical models [9]. The robustness of these approaches however calls upon complex methods that move away, in a musical perspective, from a useable and comprehensible data analysis of the variability and the particularity of instrumental gestures. Such data analysis of instrumental gestures mostly rely on trajectory analysis [5] and classification/recognition methods of trajectory parameters ([10] [12]).

3 Method

The analysis of timpani performance is directed by the present methodology (Figure 1), taking advantage of a timpani performance database and yielding to the extraction of gesture parameters that can be used as gesture inputs for the control of physically-based humanoids.

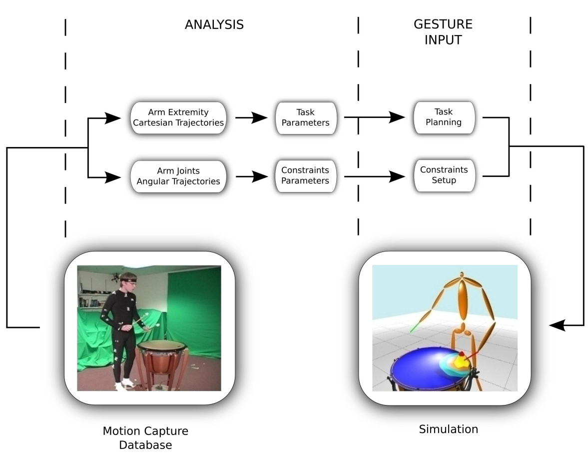

Figure 1: Methodology for the analysis of timpani performance.

A motion capture database was created, where three timpani players were asked to perform the capturing protocol designed for taking into account various timpani playing situations: drumstick grips, beat locations and musical varations. The motion was originally recorded using a Vicon 460 system with 6 cameras, sampled at 250 Hz. Markers have been placed both on the whole body of the performer (according to the Plug-in Gait model) and drumsticks. Each motion capture session results in the processing of the motion for a skeleton model (BVH format), including the position and orientation of the 19 joints composing the skeleton model.

The analysis of timpani instrumental gestures is achived by a two-level scheme considering task and constraint spaces. The task space can be defined as the 3D cartesian space containing end-arm and drumstick trajectories. The constraint space can be defined as the angular strategies that affect the physical components which condition the behavior of the performer, as angular trajectories and their derivatives can directly be correlated to joints' physical parameters such as stiffness or viscosity.

The parameterization of these spaces (task and constraint parameters) can be used as gesture inputs for the dynamic control of virtual characters [3] by task planning and constrain setup. In this paper, we focus especially on this parameterization step for studying the effect of drumstick grips on timpani instrumental gestures for the subjects S1 and S2.

4 Grip Effect: from the Tip of the Drumstick to Arm's Articulations

Variations in timpani playing range from drumstick grips, beat locations, to musical variations [3]. The present paper focuses specifically on the effect of french (F) and german (G) grips on timpani instrumental gestures, based on the analysis of beat attacks performed by two subjects S1 (French grip) and S2 (German grip). We focus on spatial and temporal differences that emerge from the analysis of the vertical component of the tip of the drumstick, as well as informations about arm articulations (shoulder, elbow, wrist) explaining these diffferences.

4.1 Axis Convention

Figure 2 defines the XYZ global coordinate system that has been used during motion capture sessions.

Every joint's position and orientation is later expressed towards this global frame. Special attention should be taken regarding the expression of joints' orientations. The geometric model issued from the motion capture software expresses orientations as XYZ euler sequences, the Z axis of an articulation being aligned by convention in the continuity of the next member. Especially, the rotations around X and Z axes will be respectively refered and denoted as flexion (rX) and twist (rZ) actions.

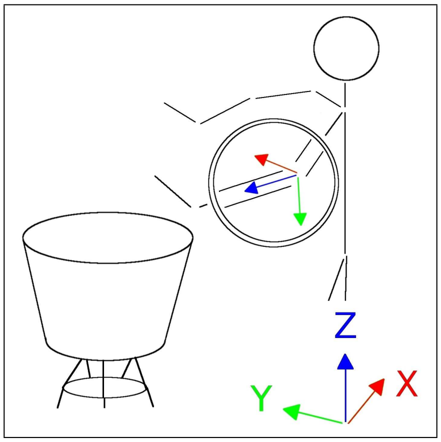

Figure 2: Experimental setup and axis convention.

4.2 Vertical Component of the Tip of the Drumstick

Quantitative features (Table 1) processed on the vertical component of the tip of the drumstick show that S1 (French grip) performs the same timpani gesture with much more amplitude. The mean of the height of the tip of the drumstick for the subject S1 is about twenty centimeters higher than for S2 (German grip), with a variance twice as high. This fact is strengthened by the vertical range of motion of the tip of the stick for S1 that is about twice as high than its counterpart for S2. The mean of the height of the tip of the drumstick shows moreover that the tip of the stick is in average closer to the timpani membrane for S2.

Table 1: Vertical component of the tip of the drumstick.

Subject (Grip)	S1 (F)	S2 (G)
Mean [mm]	1133	909
Variance [mm]	111.2	46.1
Range of Motion [mm]	434.2	178.6

Characteristic local extrema can also be observed during the preparatory gesture of beat attacks. Figure 3 presents an example of the vertical component of the preparatory gesture between two beat attacks, and the identification of three characteristic extrema denoted E1, E2 and E3. These extrema are temporally (temporal apparition in percentage of gesture's duration) and spatially characterized in Table 2.

Table 2: Local extrema of the vertical component of the tip of the drumstick: average temporal (in percentage of gesture's duration) and spatial characterization.

Subject (Grip)	S1 (F)	S2 (G)
E1 [% / mm]	21.2 / 1255.6	12.0 / 916.95
E2 [% / mm]	47.6 / 1059.9	68.3 / 881.58
E3 [% / mm]	68.4 / 1258.9	85.2 / 1022.4

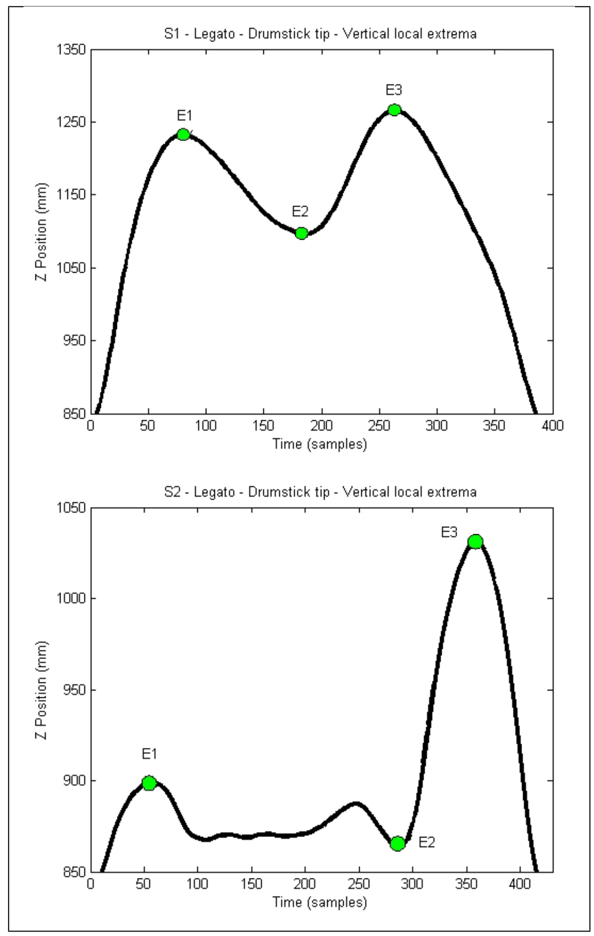

Figure 3: Local extrema of the vertical component of the tip of the drumstick for S1 (top) and S2 (bottom) between two beat attacks.

Vertical extrema E1, E2 and E3 (Table 2) are temporally equi-distributed for S1 showing a continuous preparatory gesture, whereas local extrema for S2 denote three discontinuous parts. E1 corresponds to the reaction of the previous rebound, between E1 and E2 the tip of the drumstick seems to seek a rest position (during more than the half of the whole movement duration) just above the timpani membrane, while E2 and E3 correspond to the amplitude that S2 gives for the next beat attack. Table 2 quantifies also the effect of the french and german grips on the vertical amplitude of the extrema.

French and german grips influence spatial and temporal characteristics of height of the tip of the drumsticks. The rest position between the extrema E1 and E2 for S2 could be explained by the proximity of the tip of the drumstick to the timpani membrane.

4.3 Shoulder Constraints

The analysis of the range of motion (Table 3) of shoulder's orientation and elbow's position shows that the upper-arm articulations of S2 are much more constrained than for S1. The range of motion of shoulder angles of S2 is so limited (between two and seven times lower than for S1) that the position of the elbow is almost constant. This could explain why the vertical amplitude of the tip of the drumstick for S2 is lower than for S1.

Table 3: Shoulder and elbow range of motion.

Subject (Grip)		S1 (F)	S2 (G)
Shoulder angle [°]	rX	27.00	8.42
	rY	21.81	2.97
	rZ	22.21	11.98
Elbow position [mm]	X	98.2	13.3
	Y	133.5	31.9
	Z	68.5	9.8

The stiffness of the upper-arm is influenced by the drumstick grip, and partly explains the difference in the amplitude of the drumstick. Elbow and wrist angle strategies also emphasize these differences.

4.4 Elbow and Wrist Constraints

Figure 4 shows the importance of the flexion of the elbow (S1) and the twist of the wrist (S2) angle trajectories. For both subjects, we can indeed correlate the temporal apparition of the extrema of these angles to the temporal apparition of the extrema quantified on the vertical component of the tip of the drumstick (Figure 3).

The relationship between elbow and wrist articulations for flexion and twist angle trajectories (Figure 4) shows morevover the trend of the wrist in amplifying different angles. For the subject S1, the flexion angle of the wrist is amplified towards the flexion angle of the elbow during the whole duration of the movement. Whereas for the subject S2, the twist angle appears more predominant as it is amplified towards the twist angle of the elbow during the whole duration of the movement.

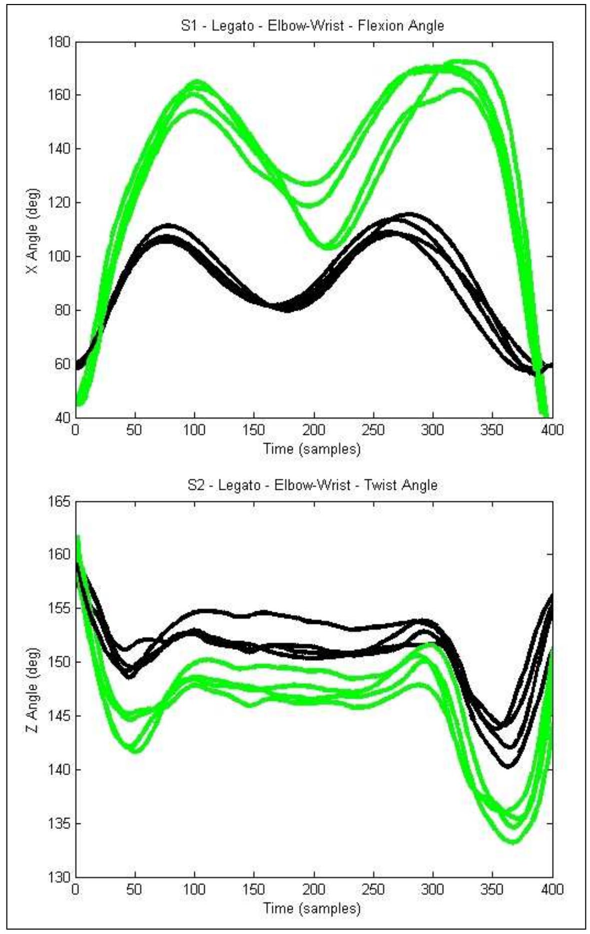

Figure 4: Intra-subject relationship between elbow (dark) and wrist (light) regarding flexion and twist angle trajectories for the subjects S1 (top) and S2 (bottom) between multiple beat attacks.

Due to this amplification relationship between elbow and wrist angles, we focus only on the elbow articulation for the flexion and twist angle trajectories for comparing S1 and S2 trajectories (Figure 5). For both flexion and twist angles, two different strategies can be put in evidence.

The flexion angle for S1 shows the same oscillatory motion as the drumstick, whereas S2 seems to lock the flexion angle to a low value for about the half of the movement, until the late preparation of the next beat attack.

As for the twist angle, two opposite strategies are used. On the one hand, for S2, the twist value at impact is very high, so that the interior of the forearm almost faces the timpani membrane. During the preparatory gesture, the twist angle is almost locked and the subject lately tends to gain momentum by decreasing this twist angle. On the other hand, S1 seems to less constrain the twist angle (attested by the variation during the preparatory gesture) and tends to gain momentum by increasing the twist angle between two beat attacks.

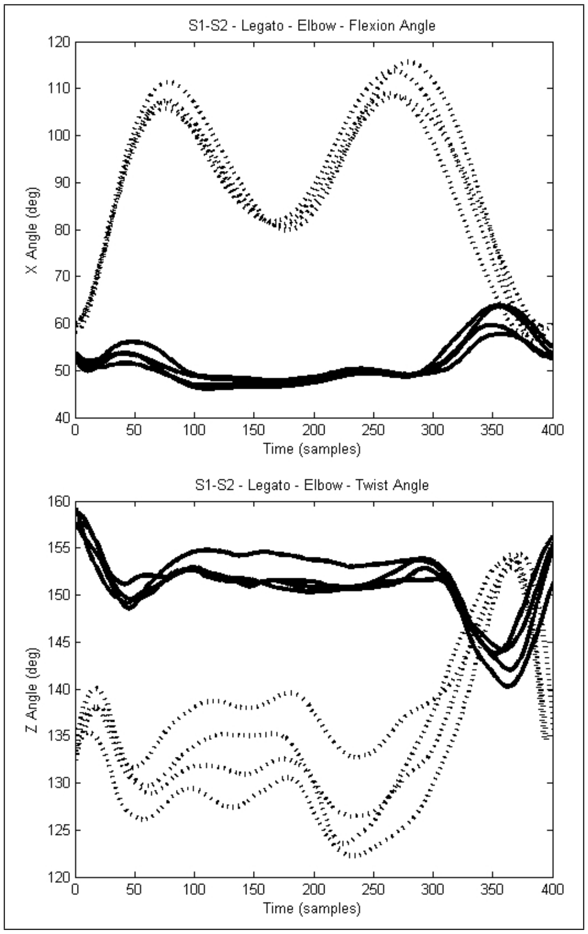

Figure 5: Inter-subject comparison of elbow flexion (top) and twist (bottom) angle trajectories for the subjects S1 (dash) and S2 (plain) between multiple beat attacks.

5 Benefit of Task and Constraint Parameterization for the Synthesis

Our system currently allows the simulation of virtual timpani instrumental situations, and the retrieval of kinematic and dynamic characteristics about timpani instrumental gestures (Figure 6). It takes directly angular trajectories as raw inputs from the motion capture database for the physical simulation of timpani instrumental gestures [3]. This input step thus does not discriminate between timpani playing styles that are inherent to performers.

The parameterization step described in section 4 is the first step towards such a discrimination and the modelling of timpani gestures, in terms of providing control parameters for upper-limb postures and the planning of gestures. The two subjects S1 and S2 under study have shown different strategies, both at the task and constraints levels, underlining parameters that can be handled by our system.

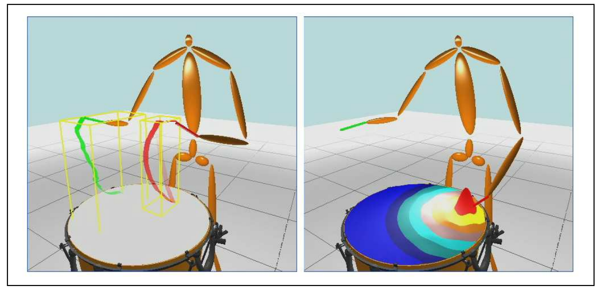

Figure 6: Retrieval of kinematic and dynamic motion cues thanks to the simulation framework of timpani instrumental gestures.

As for the task level, the local extrema that have been observed on the height of the tip of the drumstick are used as task control inputs to our system. Spatial and temporal characteristics yield the planning of timpani drumsticks motion during the simulation. As for the constraint level, the different strategies observed on the shoulder, elbow and wrist angles are used for the constraint setup of the degrees of freedom of virtual character joints. For S1, the oscillatory motion of the flexion angles for shoulder, elbow and wrist articulations is used for the simulation process. For S2, shoulder angles can be almost locked while the modelling and simulation of the elbow and wrist articulations involves twist angles.

6 Conclusion

We have presented in this paper the identification and the extraction of percussion technique parameters. The observation of differences on spatial and temporal characteristics of the height of the drumstick for two subjects with different grips has been explained by strategies involved in upper-arm stiffness, elbow and wrist angle trajectories. Such percussion style parameters can be used as inputs for our physically-based character animation framework for generating stylistic and expressive virtual timpani instrumental situations.

Future directions include the study of the effect of other timpani playing variations on the presented parameters, we aim namely at analysing the effect of beat locations and musical variations on timpani instrumental gestures.

7 Acknowledgments

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