Motion analysis to improve virtual motion plausibility

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Abstract

By understanding the mechanisms of human-human communication, developers are trying to better address expressive communication in virtual subjects, such as agents, and consequently to improve Human Computer Interaction. The work presented here is focused on the evaluation of human motion features. The algorithms we present can be applied to virtual humanoids in order to determine if the expressive information codified in the synthesized motion are comparable to the motion of real humans acting with the same intent.

Keywords: Motion Analysis, Virtual humanoid plausibility

1 INTRODUCTION

In the last few years one of the key issues of the Human Computer Interaction framework is the design and creation of a new type of interfaces, able to adapt HCI to human-human communication capabilities. In this direction the ability of computers to detect and synthetize emotional state is becoming particularly relevant, that is, computers must be equipped with interfaces able to establish an *Affect Sensitive* interaction with the user, in the sense defined by Zeng et al. 2009.

To synthesize correctly the emotional expressive information to be conveyed by virtual humanoids motion, it is necessary to study the mechanism used by humans to use and read this high level content. In human-human interaction the communication of emotional expressive content takes different channels of communication that includes also full-body motion.

In this paper we present a method for measuring two motion features: impulsivity and smoothness. Impulsivity indicates wether or not movement presents sudden and abrupt changes in energy. For example, an unexpected danger like a car approaching a person crossing the street may induce a sudden and impulsive reaction in the person movement, due to the emotion of fear/terror. Smoothness identifies the continuity/fluency of movement. Happy and relaxed persons usually communicate their state by producing body movements that are very fluent and continuous. Instead, angry and tensed persons perform quick and short body movements exhibiting abrupt changes in limbs curvature/speed.

2 IMPULSIVITY

2.1 DEFINITION

In our context *Impulsivity* can be seen as a "a short time perturbation of the subject motion state". Referring to physics we focus on the Impulsive Momentum Theorem, where an impulse can be considered as a variation in the momentum of an object to which an external force is applied. If Force and Mass are considered as constants then the following rule is true: $I = F \triangle t = m \triangle v = \triangle p$ and knowing the starting and the ending velocities: $\triangle p = m(vf - vi)$.

The underlying concept of this theorem considers the impulse as a variation of the momentum, that is, *a perturbation of the state*. In psychology Impulsivity is an important aspect to consider for evaluating some specific pathologies. In this area we found the following definition: "actions that are poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation and that often result in undesirable outcome ". From this definition we can observe that an impulsive behavior or gesture lacks of premeditation, that is, it is performed *without a significant preparation phase*. In the work of Heiser et al. 2004

on Hyperkinetic Disorders we found a characterization of the impulsive motion that "was 3.4 times as far, covered a 3.8-fold greater area, and had a more linear and less complex movement pattern". Heiser concludes that an impulsive motion can be read as *linear, without complex pattern*. From the work of Wilson et al. 1996 on the structure of the natural gesture we highlight analogies between impulsive gestures and beat gestures, characterized by short duration and high magnitude. The main research that helps us in our definition is the Theory of Effort by Laban and Lawrence 1947, that identified four Effort Qualities in human movement: Flow, Weight, Time, and Space.

By integrating all the approaches found in our overview we obtained the following definition of impulsive gestures: gestures performed without premeditation, i.e. looking to the motion phases with a very short or absent preparation phase; gestures performed with a simple pattern, i.e. simple shape performed; gestures characterized by short duration and high magnitude; gestures performed with Time = sudden and Flow =free in Laban terms.

2.2 ALGORITHM

The algorithm for the automatic evaluation of impulsivity, has been implemented in the EyesWeb software platform (www.eyesweb.org) using the EyesWeb Expressive Gesture Library Camurri et al. 2004 to extract motion features as for example energy, called Quantity of Motion (QoM). To identify the gesture duration we use motion segmentation based on the motion bells identified by thresholding the QoM. In this work we set the threshold of the normalized energy equal to 0.02, since we work in a controlled environment. A motion with energy higher then such threshold can be considered with "high magnitude". To respect the characteristic of "fast"execution, we fixed (considering also the state of the art in this context) a time duration $dt = 0.45 sec$ to discriminate the impulsive gesture, with an attack phase of $dta \leq 0.15 sec$. In Figure 1 there is an example of Impulsive gesture in term of QoM and Time duration.
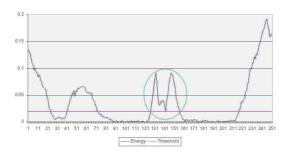

Figure 1: This is the graph of the energy motion feature with respect to the threshold value. In the green circle is highlighted the motion bell related to the impulsive gesture.

From empirical considerations, to rapidly modify actual motion, it is necessary to rapidly modify posture and in particular to modify the body occupation of space, that is Eyesweb corresponds to the Contraction Index motion cue. The calculation of this cue can be performed during the gesture execution, without introduce additional delay in the final evaluation.

The algorithm can then be written as:

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let △t = 0.45sec and let gesture threshold = 0.02;
if (energy ≥ threshold) then evaluate the GestureTimeDuration dt;
If dt ≥ 0 and dt ≤ △t then ImpulsivityIndex = △CI/dt;
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3 SMOOTHNESS

3.1 DEFINITION

From English dictionary, *smooth*: "free from or proceeding without abrupt curves, bends, etc.; allowing or having an even, uninterrupted movement or flow". In mathematics, smoothness is linked to the speed of variation, that is, a smooth function is a function that varies "slowly" in time; more precisely, smooth

functions are those that have derivatives of all orders. In music smoothness corresponds to articulation in music performance, as for example stated in DiPaola and Arya 2004. In psychopathology, smoothness of human movement could allow one to diagnose psychological disorders, for example schizophrenia: patients movements are described "staccato-like, jerky and angular", while they become "smooth and rounded" after successful therapy, as reported in Wallbott 1989. Gallaher 1992 refers to smooth and fluid movements: "an individual high on this factor has a smooth voice, flowing speech and gestures, and a fluid walk; such a person would appear graceful and coordinated ". Smooth/fluid movements are often associated with slow, sluggish and lethargic movements, in contrast with large and energetic body movement. Slowness in movements corresponds to the definition of smooth functions as slowly varying functions in mathematics.

Wallbott measured displacement of hand in psychiatric patients behavior and found four main movement characteristics: space, which describes the extension of movement; hastiness, which is related to speed and acceleration; intensity, which describes the energy of a movement; fluency-course, which is related to the quality between the beginning and the end of a movement. Wallbott states that smoothness is a possible value for the fluency-course characteristics, thus demonstrating the importance of such parameter in describing movement quality.

3.2 ALGORITHM

Research work reported by Todorov and Jordan 1998 demonstrates a correspondence between (i) smooth trajectories performed by human arms, (ii) the minimization of the third-order derivative of the hand position (called *jerk* in physics) and (iii) the correlation between hand trajectory curvature and velocity[1]. In our work we use an approach similar to (iii) to check whether a trajectory is smooth or not by computing the trajectory curvature and velocity. Other researchers like Sezgin et al. 2006 investigated the same characteristics in sketch recognition algorithms, to determine the corners of a curve, that is, the points in which curvature is high and velocity is low.

The input to our system consists of video frames frames at 60 Hz showing a moving person. During the preprocessing phase, for each video frame the system extracts the 2D position (x,y) of the barycenter of a green marker placed on the person right or left hand and stores it in a buffer consisting of 60 samples, while the oldest element of the buffer is discarded. The hand position buffer is then provided as input to the smoothness computation algorithm: for every sample (x,y) in the buffer we compute curvature k and velocity v as:

$$k = \left| \frac{x'y'' - y'x''}{(x'^2 + y'^2)^{\frac{3}{2}}} \right| \quad v = \sqrt{x'^2 + y'^2} \tag{1}$$

Where x', y', x'' and y'' are the first and second order derivatives of x and y. To compute them from the buffer of samples (x,y) we apply a Savitzky-Golay filter (Savitzky and Golay 1964). This type of filter provide as output both the filtered signal and an approximation of the $n - th$ order smoothed derivatives.

Then we compute the correlation between trajectory curvature and velocity. However, k and v are computed over a "short" time window, so we could approximate the covariance $\sigma_{log(k),log(v)}$ with 1, as the k and v variate (or not) approximately at the same time. In this way the correlation coefficient can be computed by the following formula:

$$\rho' = \frac{1}{\sigma_{log(k)}\sigma_{log(v)}} \tag{2}$$

We use ρ' to determine the amount of human hand trajectory *Smoothness Index*, as shown in Figure 2. The upper part of the Figure shows the trajectories of the performer hand: a continuous smooth circle on the left and a square shape performed with movements exhibiting sharp direction variations. The bottom part reports the information provided as output by our system EyesWeb in realtime: the trajectory as it was detected by the program and the trajectory Smoothness Index computed as explained above. As shown, the index is high for the circular smooth trajectory, while it drops to very low values for the square shape. These empirical results demonstrate show that our algorithm is able to correctly distinguish between smooth and angular movements, even if further refinement tests should be performed in future.
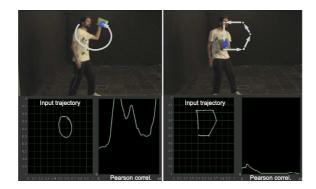

Figure 2: Round and a square trajectories: Smoothness Index is high when computed on the round smooth trajectory (left) and is approximately zero when computed on the square non-continuous one (right).

4 CONCLUSION

The main focus of the presented work is on motion analysis. We highlight how humans use motion to communicate expressive information with the aim of implementing them in virtual agents. The algorithms proposed are related to the evaluation of two motion feature in the real human full-body motion: impulsivity and smoothness. Future work includes the validation of the proposed methods using our video corpus of recorded motions performed by professional dancers, martial arts experts and students. The aim is to compare the data computed by our algorithms with subjects rates, and to refine the automatic features extraction. After this validation, the algorithms will be applied to the motion of virtual humanoid since they work on video streams in real-time.

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