Quality of Movement

Don Herbison-Evans

Newton supposedly had an apple fall on his head which inspired him to work out the universal law of gravitation. What he perceived was an object starting from rest, with no velocity, then accelerating and accelerating until it was stopped by his head, just before which it had considerable velocity, and after which it had zero velocity again. The acceleration due to gravity is about 10 metres per second, per second (known to its friends as "g"), so a graph of velocity versus time can show the movement of the apple as in figure 1



figure 1 velocity of an apple falling under the influence of gravity

Notice that the velocity of the apple after one second is indeed 10 metres per second, but it becomes zero rather suddenly when the apple hits Newton's head. By the end of that one second, it has fallen a distance equal to the area under the triangle (velocity x time) which on this graph is about five metres.

People generally do not move as this apple did. Consider swinging a leg forward from behind the body during a forward walk, for example the man's first step in a Feather Step in the Slow Foxtrot. For this he uses two sets of muscles. One set he uses pull the leg forward, so these accelerate the leg, starting it from rest behind the body, and swinging it to be in front. The other set which can pull the leg backward, can be used to decelerate the moving leg as it approaches the desired position ahead of the body, so that the leg has stopped moving again when he wants to transfer our weight to it. So halfway through the movement he just switches from using one set of muscles to using the other set. This involves a degree of neuro-muscular coordination that typically takes people the first 18 months of their life to achieve.

If each set of muscles applies a constant force during its period of activity, then by Newton's second law during the first part of the movement there will be a constant acceleration, and during the second part of the movement there will be a constant deceleration. Assuming the two sets of muscles give the same force, just in opposite directions, the graph of velocity versus time (to the same scale as figure 1) will look something like figure 2:



velocity of the moving foot for the man in the first step of a Feather step in a Slow Foxtrot (same scale as in figure 1)

In a Slow Foxtrot, at 30 bars per minute, and a "Slow" taking two beats, the first step of a Feather Step will take about one second. The area under the graph is the length of the stride, in this case approximately one metre. This makes the peak foot velocity in the middle of the stride about two metres per second.

In the next figure, I have magnified and redrawn that graph with a change of scale on the each axis:



figure 3 as for figure 2 with scales changed

This graph is hard to believe. Surely, nature abhors straight lines? Do we really move so that our velocity/time diagram is made of straight lines? One is tempted to suggest that graph would be more organic, maybe like figure 4



possible natural foot movement during walking

I have experimented with animated figures, using velocity graphs like figures 3 and 4, comparing them for how natural they look. I found that moving like figure 4, the quality of the movement looks weird. Moving like figure 3, the quality of the movement looks natural and normal.

But dancing a Slow Foxtrot is not normal. In Ballroom dancing, we try for a quality of movement that is quite different again from that of a normal walk. For example, in normal walking, the body rises as the centre of gravity passes over the standing foot. In Ballroom dancing, we eliminate this effect, and control the body rise and fall to be sympathetic to the music and the figure being danced.

One special quality that is desired in Ballroom dancing is to have "Body Flight", with the body moving at nearly constant velocity across the floor, independently of the accelerating and decelerating movements of the legs. This can be facilitated by making the legs move at constant speed through most of the stride, as in figure 5:



figure 5 foot movement to assist with constant body speed

The constant velocity segment of this type of graph is commonly controlled in dancing by using a little pressure on the moving foot, as though it is stroking the floor.

A rather different quality of movement is required in Latin-American dancing. In this, what is needed is often called "Foot Speed". Then the body can move through the hips during the time between beats, and the leg and foot only move at the last possible moment, at the end of the beat.

For example, if we take a Rumba at 25 bars per minute, with 4 beats to a bar, that gives 0.6 second between beats. The maximum acceleration of the moving foot will be limited by friction of the standing foot on the floor. Because action and reaction are equal, the force required to move a foot forward will be equal to the backward force on the standing foot. The coefficient of friction of many surfaces such as a dance shoe on a dance floor, is about 1.0, which means that in a simple situation the maximum forward force cannot exceed the weight of the body. If one attempts to accelerate the body across the floor at more than 1g, the standing foot will likely slip.

So considering the taking of a Latin step size of about 0.3 metre and accelerating (and decelerating) the moving foot at about 1g, a few back-of-an-envelope calculations will show that the velocity/time graph would look something like figure 6:



figure 6 delayed foot movement requiring foot speed

This illustrates the fact that the foot can be delayed by about 1/4 of a second before it moves in the Rumba, and then its peak velocity is actually a little less than the peak velocity of the foot taking a "slow" in the Slow Foxtrot.

So far I have only talked about the two slowest dances. The movements involved in the faster dances like the Viennese Waltz and the Quickstep are three and four times faster than these. For such dances, foot accelerations greater than 1g are useful. Advanced dancers have techniques for achieving this.

One idea is to compress the standing leg before moving. This is commonly taught in the Waltz and the Samba. The subsequent straightening of the standing leg, as the other leg moves, increases the pressure on the floor of the standing foot, allowing accelerations up to 2g. However this technique cannot give accelerations faster than 2g without the standing leg doing a hop.

Another technique is to start the body moving ahead of the leg, taking the body off balance until the moving foot actually contacts the floor again at the end of the step. This can allow a further increase in foot acceleration.

The study of such techniques requires a much more subtle biomechanical analysis than is implicit in the simplistic analyses I have done here. There is a whole discipline called "Laban Movement Analysis" in which one learns to examine a fleeting movement, such as a step, in terms of abstract quality dimensions such as flow, space, weight, and time. Needless to say, it takes a considerable period of study and guidance to learn to observe and understand actions happening for example in the fractions of a second between the beats of the music.

Stepping on the beats themselves is marching. Controlling the quality of movement in the periods between the beats: that is dancing.

donherbisonevans@outlook.com 16 January 2014