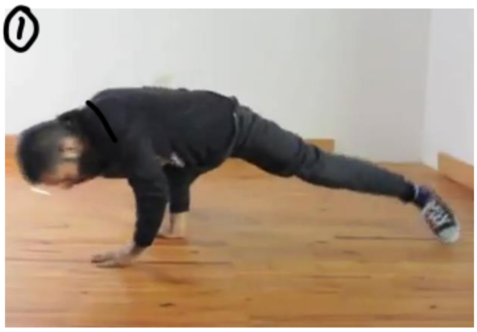
Mathematics and Street dancing

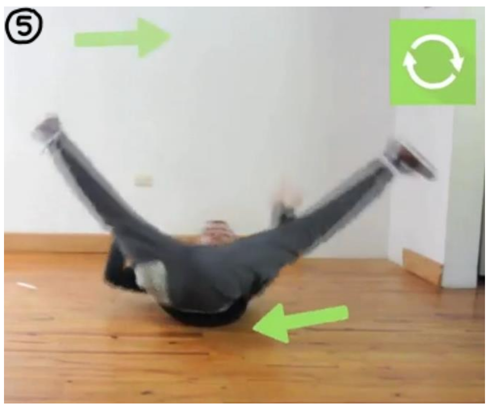
Introduction

When you think of the word ‘dance’, the thoughts of movement, music, and rhythm often come to mind. Mathematics and dance are not a common thought of combination yet the two are very intertwined when creating mesmerising performances. From the angles that ballet dancers must keep their limbs to the optimisation of stage space when curating choreography, all forms of dance implement key mathematical ideas. One popular type of dance is street dancing; a term used to describe a collections of dance style involving hip hop, krumping, popping, and more. Street dancing incorporates mathematical frameworks, like symmetry and geometry in movements of the body as well as group routines, and understanding rotational force and balance when performing moves done whist suspended.

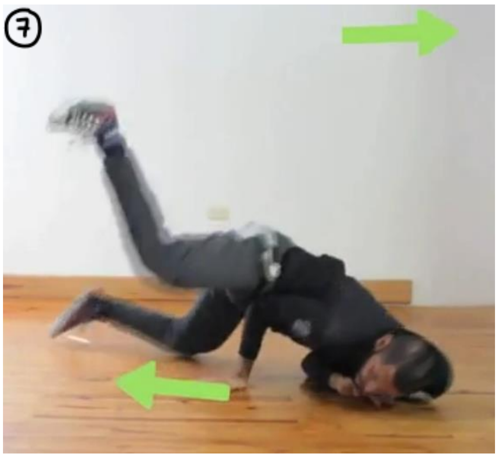
Centre of mass

The centre of mass is a theoretical concept used as a reference point for calculations. It is the point of a particular where its total mass is said to be concentrated. If a force is applied to the points, the object accelerates with no rotation. This means a force applied to any point that is not the centre of mass will result in spinning and rotation; a fact that is very beneficial when conducting certain moves in street dancing. The centre of mass of an object is also relative to its base, which allows us to check its stability. This is important in determining the positions that the body must be held in when executing dance moves where the body is held or moving through the air. These two ideas create the basis for a popular dance move ‘the windmill’.





7



8

During this move, a person's torso moves in a rigid body motion as it spins around the centre of mass. However, having the limbs extended and elevated throughout, positions the centre of mass to be relatively higher. This means when the body starts spinning, it is easier to maintain the motion. Due to air resistance and friction with the ground, energy must be continually provided to keep the rotating motion, which is done by swinging the legs as seen in steps 3-6. The force that causes rotation is called torque (τ) and can be measured by the following formula:

$$\tau = I\alpha$$

Where I is the moment of inertia and α the angular acceleration. To find the magnitude of torque needed to maintain the rotating motion we must calculate the I and α values.

$$I = mr^2$$

The legs are located the furthest from the axis of rotation and sweep out in a large circular path, meaning they will contribute to the most rotational inertia. Therefore, we will take the moment of inertia of the both legs. Taking the mass of the dancer carrying out this move to be 75kg, the mass of each individual leg will be around 16.7% of the body weight resulting in around 12.5kg. The distance of the legs from the axis of rotation will be around 1.4m. This means the moment of inertia will amount to:

$$I_{leg} = 12.5 \times (1.4)^2$$

$$I_{leg} = 24.5\ kgm^2$$

$$I_{legs} = 2 \times 24.5$$

$$I_{legs} = 49\ kgm^2$$

Assuming the dancer starts from rest and takes one second to complete a full rotation, the angular acceleration can be calculated as follows:

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

$$\omega = \frac{\theta}{t}$$

$$\omega = \frac{\pi}{0.5}$$

$$\omega = 6.28\ rad/s$$

$$\alpha = \frac{6.28}{0.5}$$

$$\alpha = 12.57\ rad/s^2$$

Therefore,

$$\tau = I\alpha$$

$$\tau = 12.57 \times 49$$

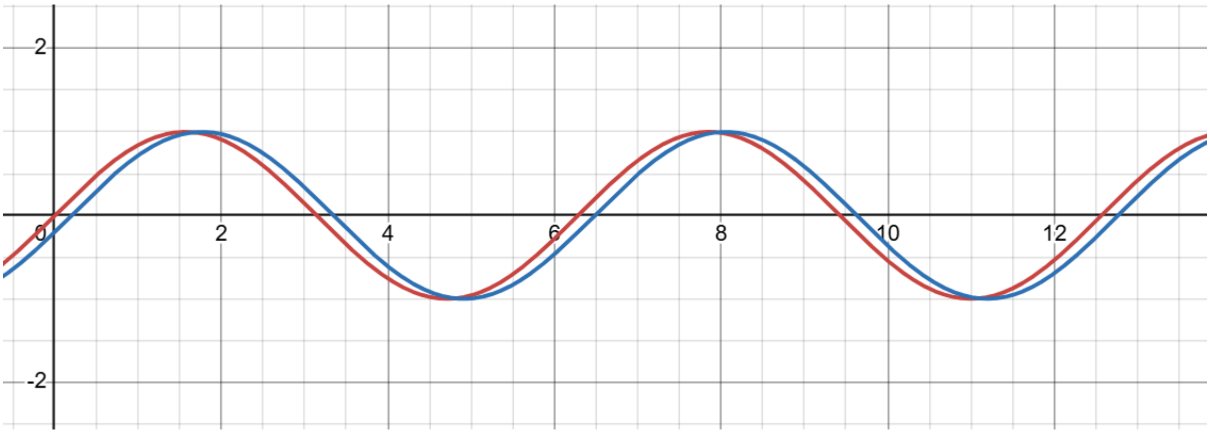
$$\tau = 615.93\ Nm$$

This means a torque of 615.93 Nm is required to turn rotate the body to complete a full windmill rotation.

Group dances and choreography:

Dance choreographers have a crucial role in creating dance performances to keep audiences engaged and anticipating the next move. A commonly occurring theme in group dances is synchronisation and symmetry. Symmetry in a dance creates forms that are visually pleasing to audiences. Dancers can form mesmerising shapes and patterns on stage as shown below.

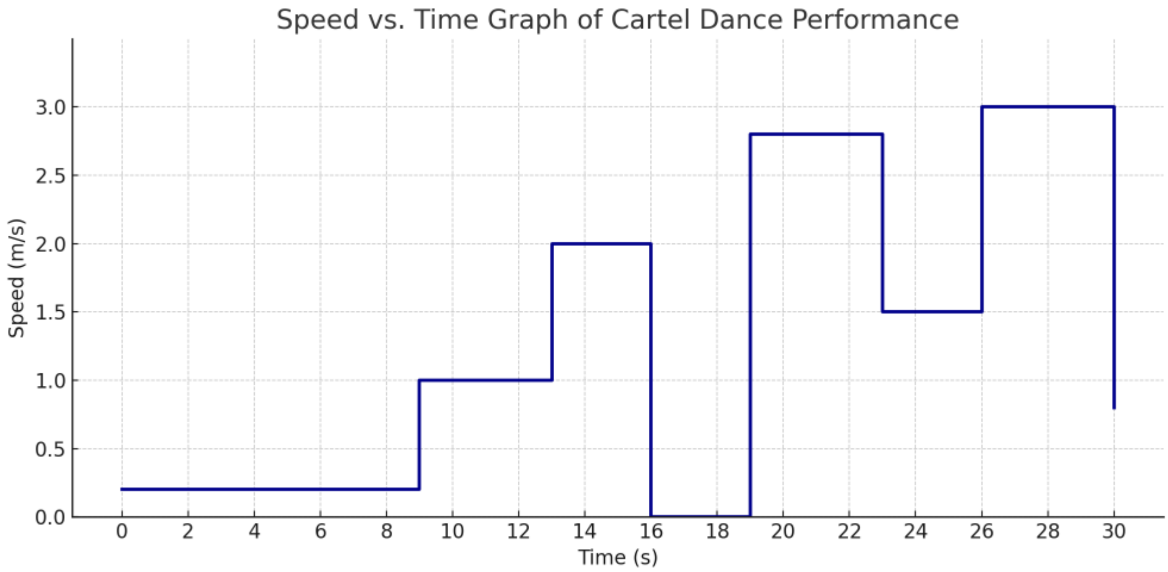
Mirrored formations and shapes on stage captures and holds the audience's attention as well as providing a fluidity to the motions. A visual harmony is created which creates a strong impact on stage. Moving together in sync augments the sense of unity and enhances the fluidity, which amplifies the power felt from each movement on stage. For example, when jumps and hand movements are made in unison, the audience's excitement is heightened and their attention is pulled in. Remaining in a synchronised formation is important in street dancing when competing in dance battles. A lot of practice goes into ensuring a whole group moves together however it makes their performance look more disciplined, highlighting their technical skill and control. A sine graph can be used to show the motion of two dancers.



A graph of two dancers completely in sync would show both the blue and red graph lining up. As shown above, the slightest of delays in timing can result in altering the lineup of the entire choreography. This emphasises the importance of control and awareness a dancer must have to the music and to each other.

Symmetry also aids in conveying themes and ideas; dances incorporating symmetry can represent harmony and peace whereas performances whereas breaks in symmetry can be intentionally used to symbolise disruption and chaos which play on emotional themes of dance. It causes a dynamic shift in the performance which can be used when the music intensifies, forming an anticipative atmosphere.

Another method to create rises and falls in tension during a piece is through altering the speed of movements. Using slower movements when approaching a climax in the piece allows the dancers to release a sudden energetic burst. A performance on Britain's got Talent by a group called Cartel shows the significance of controlling the speed of movements has in changing the atmosphere. Taking measurements from the different movements performed in one

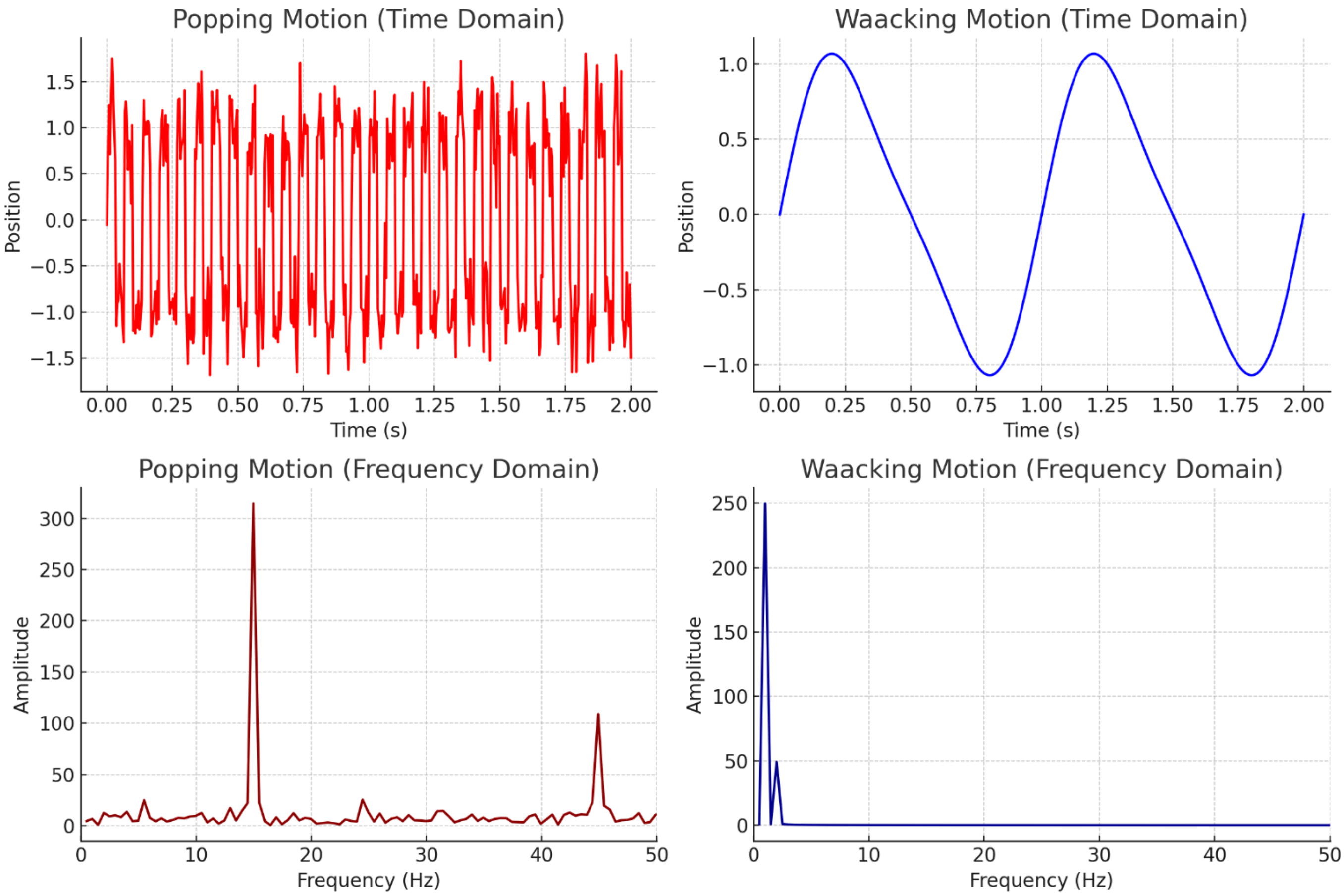


section of this dance I created a speed-time graph showcasing the how the speed changed throughout the performance in relation to the music.

At the onset, the group has a relatively slower speed as the group introduces their moves. This then progresses to the performance increasing in speed as higher energy moves are introduced.

Fourier analysis in dance

The Fourier analysis allows complex waves to be broken down into the sum of sines and cosines. This can be applied to dance as we gain an insight into how different motions are composed and their rhythms. To use this theory in practice, I took two contrasting street dance moves to see how their graphs would differ. ‘Popping’ is a dance move created when a dancer contracts and relaxes muscles to create a pop effect. It is done to the beat of music, often funk and disco. A dance move using slower, more fluid motions is ‘Waaking’. This involves making sweeping continuous arm movements in circular arc. Although they are generally performed in a fast gesture, the action is smoother and more flowing. After gathering data from analysing these two dance moves, I created Fourier analysis graphs.



The graph to the top left shows the erratic, irregular nature of popping, with the peaks representing the sharp muscle contractions – highlighting the abrupt and high energy style of this dance move. Contrasting to this, the top-right graph shows a sinusoidal curve which indicates the predictability of this move. The bottom graphs illustrate the opposing patterns in terms of the frequency spectrum. Popping has consistent amplitudes with frequencies that are in higher ranges (above 10Hz) indicating that it requires more high frequency components which correlates with the sharp transitions. Waacking, on the other hand, comprises of smooth oscillations and lacks sudden changes.

Conclusion:

Though at first many do not expect intertwinement of dance and maths to this extent, writing this essay and formulating these investigations has enabled me to value the beauty and complexity of dance. The two abstract concepts come together harmoniously, allowing us to visualise the balance, coordination, and energy dancers must distribute within themselves in order to create fascinating performances, leaving us onlookers in awe. Despite dance being expressed in movements and maths using equations and geometrical forms, both rely on balance, rhythm and timing- whether this be in complex math problems or the progression of a dance sequence. By acknowledging the intricate links between these two subjects, we are able to completely appreciate and understand the ways in which they complement one another.