Simulation of a bipedal walking style(gait) using varying optimized parameters

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***Abstract*— When we analyze the term 'gait', we define it to be the locomotion that is achieved by the motion of the human limbs. Different gait movements can be characterized by different limb movements patterns, varying energy cycles, velocities, forces or even the manner in which contact is made with the floor while in motion. These gaits can be classified into two types of gaits, Normal gaits and Special gaits. The Normal gaits are basic gaits which can be seen in everyday life with the most common examples being walking, jogging and running. Special gaits are used under certain special circumstances and involve methods of training such as using of certain forms of martial art. Gait Analysis finds itself very useful in fields such as Sports mechanics where it helps in rectifying movement related issues in people who are generally more injury prone than others and in doing so, aids in running in a more efficient manner. In this project, we study the different forms of gait and how they vary if we optimize certain parameters and at the same time, create an environment where the biped is able to adjust it's gait to match these parameters.**

I. Introduction

As part of an experiment done by German graduate students, Motion Capture is employed on high speed cameras, lights and reflectors all attached to them while they walk on a closed track or treadmill. Once a steady pace is established by one of them, 20 or so steps are recorded. At 120 frames per second, this results in typically 1440 frames. Data from the reflectors is collated into 15 standard locations on the head, torso, arms and legs. As these points move in three dimensional space, the raw data that is eventually captures based on observation is found to be an array of time series with 45 rows and 1440 columns. Taking inspiration from this setup, bipeds have been rendered using WebGL and using imitation based learning and reinforcement learning, gait patterns have been obtained.

The walking motion depicted in the project is periodic so Nikolaus Troje's model of the human gait is a five term fourier series describing the positioning of the 15 points that make up the biped in three dimensional space. The equation is of the form mentioned in the equation below.

$$p(t)=v1+v2\cos\omega t+v3\sin\omega t+v4\cos2\omega t+v5\sin2\omega t$$

Here, ω the scalar frequency is the only nonlinear parameter and is obtained by the Fourier analysis of the data. The five coefficients specified in the formula above all comprise of 45 components. Once the scalar frequency is computed, the coefficients are all computed using Principal Component Analysis of the data. Principal Component Analysis effectively reduces the 45 by 1440 data matrix to a 45 by 5 coefficient matrix. This model generally produces raw data with an accuracy better than 95%.

During the experiment, there were several dozen subjects, each with their own characteristic coefficient matrix V. When all these coefficient vectors are collected together into one big V and Principal Component Analysis is used again to reduce this to an average set of coefficients, 'everyman' is obtained.

II. PRINCIPAL COMPONENT ANALYSIS DESCRIPTION

The walk of an individual subject can be regarded as a time series of postures. Each posture can be specified in terms of the position of the 15 points constituting the biped in three dimensional space. The posture is a 45 dimensional matrix. If there is any redundancy within a dataset, Principal Component Analysis is used to capture this redundancy. Redundancy in a dataset means that the data occupies only a part of the space. If there is a walker amongst 40 who performs 20 steps in 12 secs, this would give 1400 postures. Principal Component Analysis is applied to each posture of the walker where each posture can be labeled as a combination of the average posture and the weighted sum of the first four principal components. The formula below elucidates the description

$$\mathbf{p} = \mathbf{p}_0 + \sum_i c_i \mathbf{p}_i$$

Here, p(i) denotes the ith principal component and c(i) denotes the respective score for that component. The “everyman” walker has five vector coefficients. They are simply vectors coming out of the principal component analysis. However, they can be given names based on how they each affect a certain form of motion. The first component v1, is simply a static position. It helps in determining how the walker looks at rest.

The second coefficient v2 dominates forward motion and is hence appropriately termed as a stride. The third component controls sideways motion and is termed as a sway. The fourth coefficient and fifth coefficient involve vertical motion which are in phase and out of phase with the forward stride respectively. They are termed as hop and bounce. It is when these four vectors are added to the at-rest position that the walker is obtained which is as realistic as a human gait can get. Hence, the walk of any particular subject can be interpreted as a combination of an average pose, four characteristic poses and a fundamental frequency term. The poses are all 45 dimensional vectors and the frequency is a scalar quantity.

III. WEBGL DESCRIPTION

WEBGL is a standard 3D graphics API for the web. It is based on the long established API known as OpenGL. In a typical WebGL program, there are two phases which are initialization and rendering. In the initialization phase, buffers and textures can be created and in the rendering phase for everything that needs to be drawn, there are a list of crucial function calls. The functions gl.useprogram is needed for the program to draw, gl.bindbuffer and gl.VertexAttribPointer are relevant for the attributes that are being assigned and gl.activeTexture and gl.BindTexture are useful for assigning textures. OpenGL has been used for the implementation of bipeds as part of the project.

IMPLEMENTATION DETAILS:

We plan to implement the gait simulation using three.js, a popular WebGL library. Three.js allows easy importing of mesh models making it easy to animate them. However, due to technical difficulties and paucity of time we couldn't complete the implementation in WebGL. Instead we have a working demo on MATLAB.

A coefficient vector c (which denoted the “score” of a proncipal component) is then updated by repeated convolution with the user data on stride, sway, hop and bounce. Then the principal components are obtained by using the relation mentioned earlier. The final gait data calculated as mentioned five fourier term gait equation, and applied to each of the 15 links to obtain the final gait.

The data for a gait is obtained from the gaitanalyzers.mat file which has the data for different gait under different emotional and physiological contraints.

IV. EXPECTED RESULTS

Information retrieval from movement patterns find a number of applications. When the gait is subject to changes in emotional intensity, a clear difference can be observed. When the emotion is happy, the sway of the hands is much more pronounced and the face is positioned facing upward. The gait patterns are similar to the feeling proud emotion. When the emotion is sadness, the face is positioned facing downwards and the sway of the hands is much less than when happy. Activated events such as happiness and anger are associated with faster than usual movements and deactivated events such as fear and sadness are associated with smaller and slower movements as compared to even matched neutral speed bipeds. When there are two bipeds with similar speeds, limb flexion and head inclination are found to be key differentiators.

V. CONCLUSION

It can be concluded that gaits can be modified or modulated by many factors where changes in the normal gait pattern of the biped can be either transient or permanent. In the project developed, an environment was developed where gait patterns were influenced by the vector components explained above: stride, sway, bounce and hop.

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