Adapting Motion Capture Data using Weighted Real-Time Inverse Kinematics

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***Abstract* – In this paper we present a technique that enhances an inverse kinematics (IK) solver such that when the results are applied to a computer character we can generate a level of individualisation tailored to both the character and the environment, e.g. a walking motion can become 'stiffer' or can be turned into a limping motion. Since the technique is based on an IK solver, we also have the desirable effect of solving retargetting issues when mapping motion data between characters. As the individualisation aspect of our technique is very tightly coupled with the inverse kinematics solver, we can achieve both the individualisation and retargetting of characters in real time.**

I. INTRODUCTION

One of the main issues in using motion capture data to animate human figures is the problem of retargetting. This is the issue of applying motion data captured from one person to a virtual person of a different size. Since such data is usually in the form of joint angles relating a hierarchy of pieces, a person with different limb lengths driven by the same angles will have a different end limb point. This is perhaps most clearly illustrated when the feet of characters appear to slide across the floor or penetrate it.

A simple solution would be to capture data from a real person of the same size as the virtual character. However, this is inflexible and would not work for some games characters, e.g. monsters. Thus we need a more flexible approach. This is offered by Inverse Kinematics (see [16] for a general introduction to IK), which can be used to adjust a motion. The use of inverse kinematics in the field of character animation is not a new idea; however it is only recently being exploited in real-time applications such as games.

In additional to the retargetting properties that come with an IK solver, we have further enhanced the use of our IK technique to incorporate a level of stylisation control over the character that comes at no extra computation cost. We can transform a single base motion to a character of different physiological build, and we can further adapt the motion in real time to simulate the appearance of injuries. Thus a character in a game could receive an injury and change his motion accordingly in real time using our techniques for adapting existing normal motion.

The following section gives a review of current approaches to adapting character motion. Then, after presenting the details of our technique, we demonstrate the principle by applying it to a single walking motion that we adapt to demonstrate both individualisation and injury simulation.

II. RELATED WORK

There are two general approaches to acquiring base motions for character animations. One way of obtaining the data is to record the motion of a live subject using motion capture technology (mocap) [15], while the other technique requires the motion to be simulated. The latter can itself be further broken down into several different techniques that including keyframing, inverse kinematics [12, 17] and dynamics [1] algorithms.

In many cases, it is desirable to adjust motions to meet specific environmental constraints or properties of the computer character. Generally speaking, adaptations are added onto the base motions, or variations of the simulation algorithm are used, rather than creating completely new algorithms to generate such changes. One of the first changes that generally needs to be done is to retarget the motion to a character that may have different dimensions. This is done to eliminate visual artefacts that result from motion mapping and has been successfully tackled in the past with a variety of different techniques include IK [3], spacetime constraints [4] and dynamics [5]. The former techniques tend to be less computational expensive than the latter ones and in particular, the IK algorithm we use in this paper has the ability to perform real-time retargetting in addition to the individualisation we present.

Beyond the task of retargetting characters lies the field of adapting motions to portray more complex stylisation attributes such as physiological build (individualisation) and emotion. In the past, much of the work into introducing different physiological builds into character motions has been based on dynamics and biomechanics [6, 7]. These techniques demonstrate good realism in the results, however this is at the cost of a large computational cost that would not be available in real-time applications which is where our technique demonstrates its potential.

Another area of interest for adding stylisation to base motions is in simulating a level of visible emotion. Various techniques have been used to achieve this goal including the use of Fourier principles [8, 13, 14], energy consumption [11]

and emotional posturing [2]. The latter technique introduces an emotional appearance to the character by constraining joint angles based on the emotional state of the character. Although we do not investigate this in our paper, it would be possible to incorporate this into our work to enhance the individualisation we demonstrate later in this paper, further adding value to our design.

In the following section we describe the technique that allows us to adapt an existing motion captured animation that is retargeted to both the environment and the character and to add extra richness to the motion in the form of individualisation, including injuries. All of this is achieved in real time unlike many of the existing techniques that currently rely on complex dynamics to achieve the same aim.

III. CHARACTER INDIVIDUALISATION

Our system, *MovingIK SE*, is comprised of three independent modules that communicate accordingly using a level of parameterisation that allows flexible control over the generated motions. The system's modular design is outlined in Fig. 1.1.

The Control Module is the top-level component whose purpose is to generate a set of values for the parameterised motion. The Control Module determines the parameterisation based upon Control Sources that are fed into the module as well as its stylisation state. It is the stylisation state that gives the character its individualisation. The parameterisation of the Control Module, which encapsulates the information required to produce a motion, is passed on to the Animation Module. The Animation Module takes the parameterisation as input and using knowledge about how the motion is performed, which is obtained from the Data Module, it postures the hierarchical structure of the character over time.

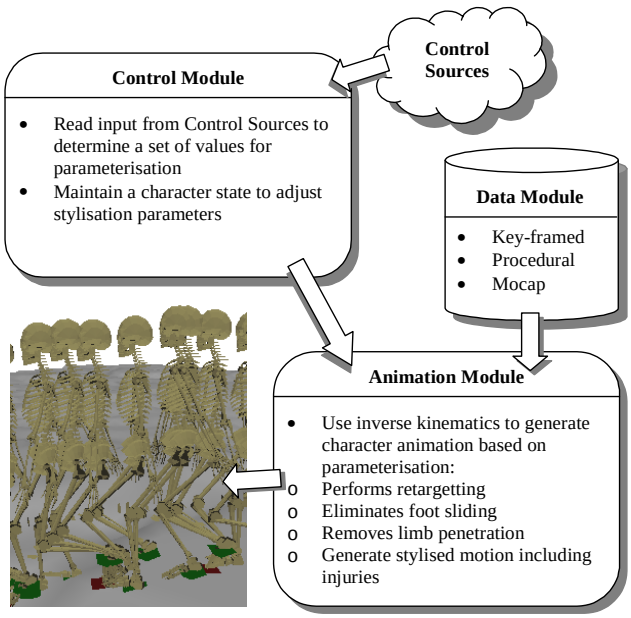


Fig. 1.1: Control Structure of *MovingIK SE*.

For the system we describe in this paper, we will be using the motion of a two-legged humanoid gait. However, with the level of abstraction we have imposed on the system, this can easily be replaced with an alternative type of motion as discussed at the end of the paper. The roles of each of the modules within *MovingIK SE* are discussed next.

A. Control Module

The parameterisation of our system is split into two subgroups. The first subgroup specifies the control parameters of the motion, while the second subgroup influences the behaviour of the inverse kinematics solution used by the Animation Module.

The control parameters of the motion are derived from a user-controlled analogue joystick whose inputs are used to initially determine the stride length, speed, and direction of travel. The Control Module subsequently adjusts these basic motion parameters in order to simulate the character's stylisation state. This, for example, could be to linearly reduce the maximum speed and stride length in order to simulate the fatigue of a character. The way in which the stylisation state affects the parameterisation is discussed later.

The second subgroup of parameters is weighting values that stiffen up joints so they move less compared to surrounding limbs. This gives rise to a basic difference in visual appearance between characters of varying weighted values. These parameters are determined by the stylisation state of the character only. The application of weighted parameters is discussed further under the Animation Module section of this paper.

The stylisation state of the Control Module can be dynamically changed in response to the system's Control Sources. These can take a variety of different forms including responses to environmental events or an AI engine. For our demonstration of producing stylised motions, we invoke the different states by keyboard input.

As well as the basic control parameters and the weighting values, we have control over hip swing parameters for the walking motion we demonstrate. The first of these parameters controls the amount of rotation there is about the vertical axis of the hips. This gives the visual appearance of swaying from side to side, with larger values resulting in the character swaying its hips more. The second hip parameter determines the amount of travel there is along the vertical axis where an increase of this parameter produces a more bouncy looking character.

It is the combination of the control and weight parameters that gives rise to realistic individualisation of the character.

B. Data Module

The Data Module provides knowledge, in the form of limb Degree-of-Freedom (DOF) values, about how to perform an action to the Animation Module. The output format allows us to model the data using a range of techniques including key-framed data, procedural models and motion-captured data, without affecting the behaviour of the other modules in the system. This allows us to choose the optimal data representation for the given scenario, for example, the use of motion capture data for high detail where storage space is not an issue, compared to procedural models for background characters.

In a previous paper we discussed how to adapt a procedural walk model [10]. In this paper, we use motion capture data, which gives a more realistic basis. To do this the Data Module extracts the DOF values direct from a motion capture file. The motion of the upper part of the body, from the hips upward, remains essentially unaltered except for a time-warping factor that is used to synchronise the upper and lower body motions.

The motion of the lower body, i.e. the legs down, is generated based on an adaptation of the original motion data. In our example, we are not just retargetting the walk motion to a new character but we are also giving our character the ability to change various parameters such as stride length, speed and direction. To achieve this we refine the leg motion into a synthesis problem whereby given a flight path for which the foot should travel, we calculate the unknown hierarchical joint angles using an inverse kinematics solution. However as we have the original motion data, we make use of this to determine the desired flight path.

Our approach of retrieving the flight path from the motion capture data is primarily based on a gradient analysis technique where, over the course of the original motion, we analyse the height value of one of the character's feet. The first target we are looking for is a switch from a negative to a positive gradient on a frame that is within 10% of the global minimum height for the foot. This gives us the start of the foot flight where the foot is just about to leave the ground.

From the first target, we progress along the original flight path until we meet a second gradient change from positive to negative which is on a frame whose height value is within 10% of the global maximum. This second target is the peak of our flight height. Continuing along the original path, the third and final target we locate via one last gradient switch

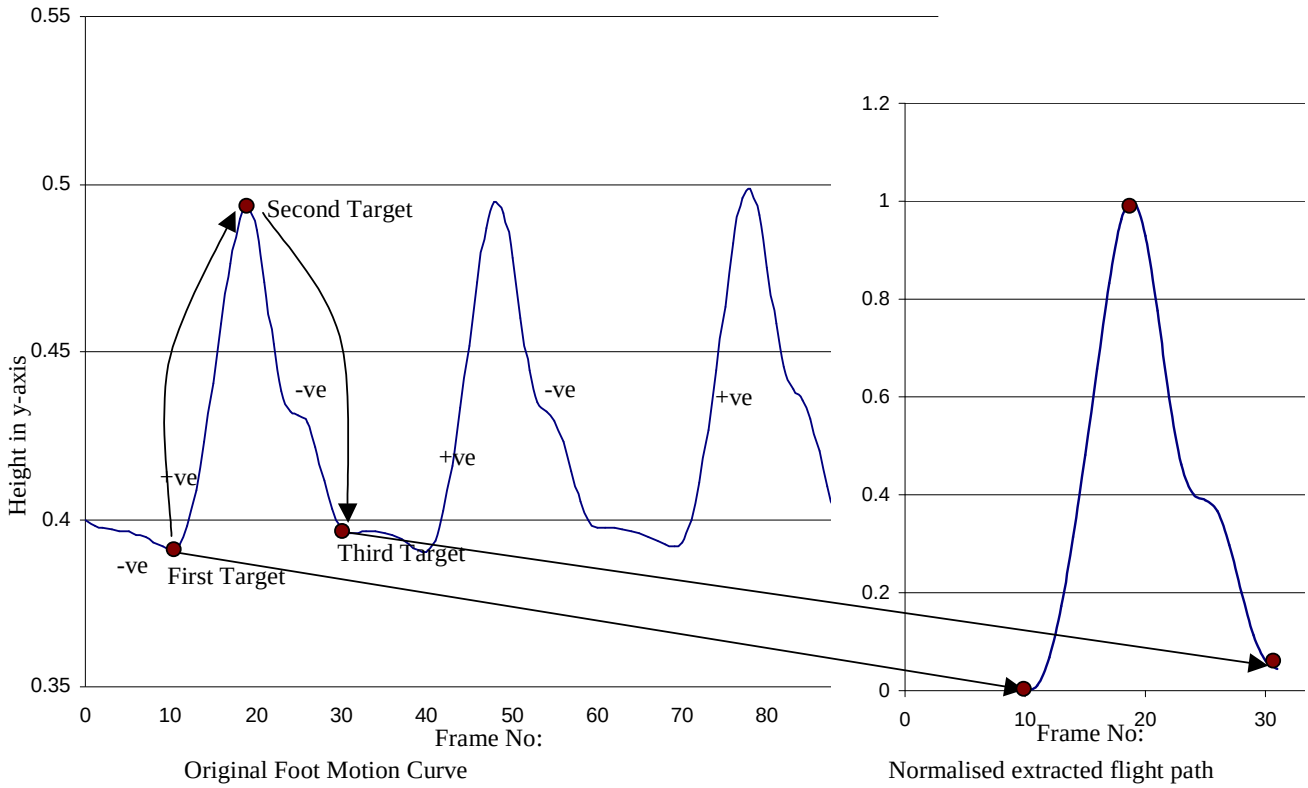


Fig. 1.2: Gradient-based extraction of foot flight from motion capture data

from negative to positive whose frame height is again within 10% of the global minimum. This technique is demonstrated pictorially in Fig. 1.2.

We include 10% threshold values when determining the target points to reduce the chances of failing to find a complete stride cycle because using local gradients alone would fail where the motion data temporarily plateaus or the motion data has a little 'blip'. For example, in Fig. 1.2, near frame 25, the motion data introduces what is almost a stationary point and, had the gradient actually changed at this point, the gradient-analysis technique would have determined this to be the third target which is obviously not the case.

Having found all three targets, we take the flight curve to be that which is described between the first and third target points. We subsequently normalise the height values so that they can be mapped onto the new character based on a ratio between the new and original character's leg lengths. We further use this ratio between the leg lengths of the characters to initially determine the stride length control parameter.

C. Animation Module

Through a combination of information from the control parameters and examination of the surrounding terrain, the Animation Module determines the extents of the motion to perform. Using knowledge about the motion, the end-effector locations are interpolated over time between the extremities and thus produce the retargeted motion. The interpolation follows a modified path whose original is obtained from the Data Module where the end-effectors are positioned along the path through the use of an inverse kinematics solver. This technique allows us to manoeuvre over uneven terrain including climbing and descending steps. The way in which we adjust the base motion for a walking character is briefly outlined in the following subsection.

The use of an inverse kinematics solution to configure the character's structure allows us to precisely position end-effector locations. This has the immediate benefit of eliminating visual problems that are apparent when playing pre-scripted animations. However pre-scripted animations are computational cheap to display therefore to compete we need to keep the resource demand for the IK solution as low as possible. To this end, we utilise a half-Jacobian-based solver [9], which allows for a more efficient and quicker solution time for IK chains over the traditional, full Jacobian solver. While the full Jacobian IK solver can operate in real-time, the half-Jacobian has a reduced footprint in terms of processor usage and hence gives a more attractive online animation technique.

The use of a Jacobian-based inverse kinematics solver has the additional benefit of allowing us to take this algorithm and embed a set of dynamic weighting values. These values are the weighting parameters that the Control Module determines and passes down to this module. The purpose of the weighting values is to give us additional control over the solution that the algorithm produces which visually generates different inter-limb movements for the same end-effector and root nodes positions. In effect, we can make use of the inverse kinematics technique to produce a level of character individualisation at no additional cost to the core algorithm. This technique is further discussed in the *Weighted Inverse Kinematics* subsection.

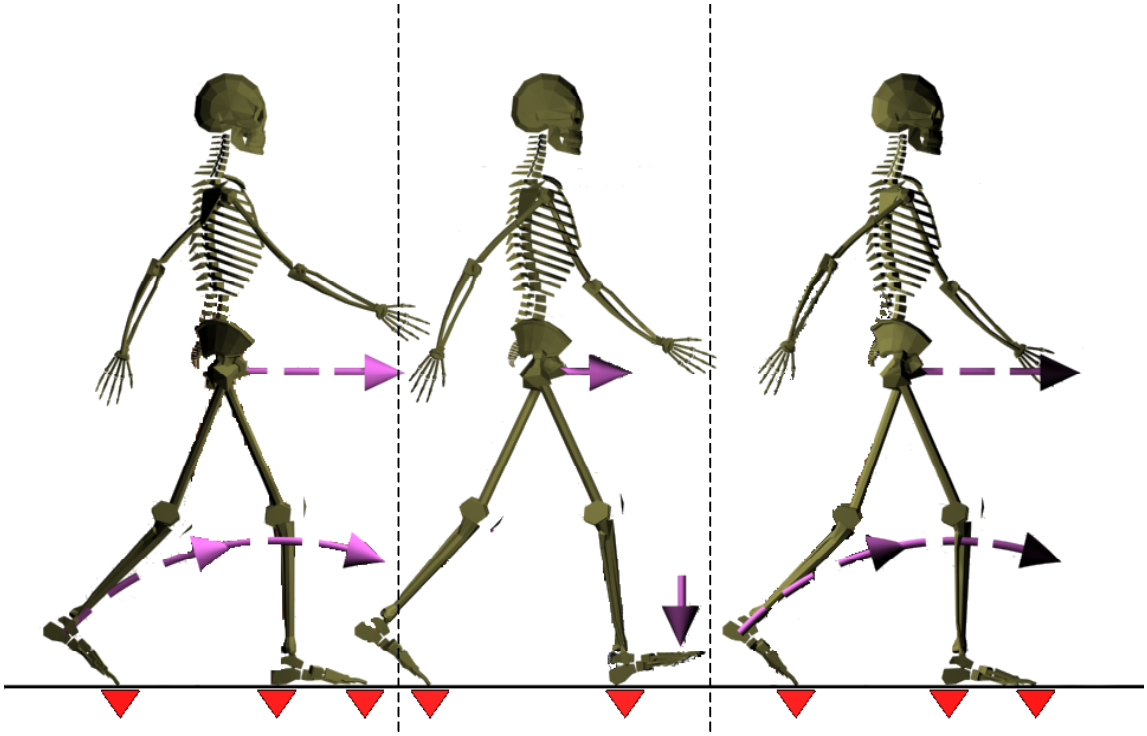
Changing the Base Motion

There are two cases under which the character can move forward: walking in a straight line or turning. The Control Module uses input from the Control Sources to determine the way the character moves. If there is no sideways movement then the walking forward technique is used otherwise a turning action is executed.

We split a complete walking cycle into two discrete movements. The first is the actual flight of the foot as the character performs a stride, while the second is a post-flight stage that rolls the foot from a heel supporting phase to a complete foot supporting phase. The post-flight phase of the

TABLE 1.1
Illustration of the 2-stage walk cycle where the initial configuration is with the left foot in front and the right foot behind the body.

Stage Description	(a)	(b)
Starting Configuration		
• Left Foot	Both heels and toes are planted on the floor	Toes are planted on the floor
• Right Foot	Toes are planted on the floor	Heel is planted on the floor
Movement	1. Hips move forward, 2. Right heel is advanced forward through the air, 3. Only the left toes remain planted.	1. Hips move forward, 2. Right toes are gravitated towards the floor, 3. Left toes remain planted to the floor



(a) Start of walk cycle (b) Final part of walk (c) Start walk cycle again on other foot

Fig. 1.3**:** Demonstration of the cycles implementing in our system. Each frame represents the start of the cycle with the arrows pointing in the direction of travel the node will take until it reaches the start of the next part of the cycle. The red triangles represent plants of the character's limbs.

walking cycle increases the realistic-looking nature of the resulting animation and gives us the ability to model the complete foot as opposed to just the heel. An overview of this procedure is outlined in Table 1.1 and Fig. 1.3, where a detailed approach of how we control the character is given in [9].

Weighted Inverse Kinematics

At the centre of the Animation Module, is an inverse kinematics engine that postures a character using end-effector locations. The algorithm we use is the half-Jacobian-base technique [9]. Due to the nature of Jacobian-based inverse kinematic solvers, we are able to predictably modify how much different DOFs change when configuring a posture thereby resulting in subtle but individualised results. This, for example, allows us to favour the rate of angle change for the knee over the hip joint.

The Jacobian, *J*, at the core of the algorithm is determined from the equation of forward kinematics, given by (1), where θ represents the set of orientation values for a structure and *X* is the global position of an end-effector in the hierarchy.

$$X = f(\theta) \qquad \textbf{(1)}$$

Taking partial derivatives of (1):

$$dX = J(\theta)d\theta \qquad \textbf{(2)}$$

where $$J_{ij} = \frac{\partial f_j}{\partial x_i} \qquad \textbf{(3)}$$

Rearranging (2):

$$d\theta = J^{-1}dX$$

Using these equations, we can describe the complete inverse kinematics solver as follows:

1) *Calculate the difference between the goal position and the actual position of the end-effector:*
$$dX = X_g - X$$
2) *Calculate the Jacobian matrix using the current joint angles: (using (3))*
3) *Calculate the pseudo-inverse of the Jacobian:*
$$J^{-1} = J^T(JJ^T)^{-1}$$
4) *Determine the error of the pseudo-inverse*
$$error = \left\|(I - JJ^{-1})dX\right\|$$

5) *If error > e then*

$$dX = dX / 2$$

restart at step 4

6) *Calculate the updated values for the joint orientations and use these as the new current values:*

$$\theta = \theta + J^{-1}dX \quad \textbf{(4)}$$

7) *Using forward kinematics determine whether the new joint orientations position the end-effector close enough to the desired absolute location. If the solution is adequate then terminate the algorithm otherwise go back to step 1.*

For our purposes, it is step 6 of the above algorithm that we are interested in which is the stage of the algorithm that updates the joint angles within the hierarchical structure. The algorithm, as illustrated above, will distribute the angle changes needed to meet the desired end-effector location evenly over the chain. However we have rewritten this stage to include a set of dynamic weights that redistribute the contribution each degree of freedom (DOF) has in the resulting motion. We therefore replace (4) with (5) in our implementation, where *W* is a weighting vector.

$$\theta = \theta + WJ^{-1}dX \quad \textbf{(5)}$$

The weighting vector, *W*, contain real values between 0 and 1 where smaller values result in less significant changes in angle compared to larger values in *W* that correspond to bigger angle changes. This principle is illustrated in Fig. 1.4 where the IK solver is applied to a simple hierarchical structure of different weighting values. In Fig. 1.4, we have reduced the weighting parameter for the first joint angle, which is at the root, and compared this with an even distribution. As the illustration demonstrates, the joint angle which has a reduced weighting moves less therefore other joints in the chain have to move more to meet the desired end-effector position. This is compared to the evenly-weighted IK chain in which each of the angles involved in the chain are changed relatively equally.

Although we have only applied a weighting change to one of the angles in Fig. 1.4, the principle of relatively stiffening up joints within an IK chain equally applies when changing multiple weighting values. However, as it can be seen from the graph of Fig. 1.4, reducing a weighting on one joint has the effector of indirectly increasing the weights of the remaining joints because the difference needs to be resolved. This cause and effect result needs to be considered when applying weighting values to an IK chain. We have found through our experiments that as long as these values are specified relative to each other, the results obtained from the solution exhibit the desired properties intended. If the weights are not determined in a relative manner but instead along an absolute scale, the visual results obtained would not necessarily follow that which is expected based on the weighting parameters.

Changing Weight Parameters to Individualise Characters

We harness the property of weighed IK chains in the Animation Module to assist in the production of motions that are individualised to characters based on the stylisation state

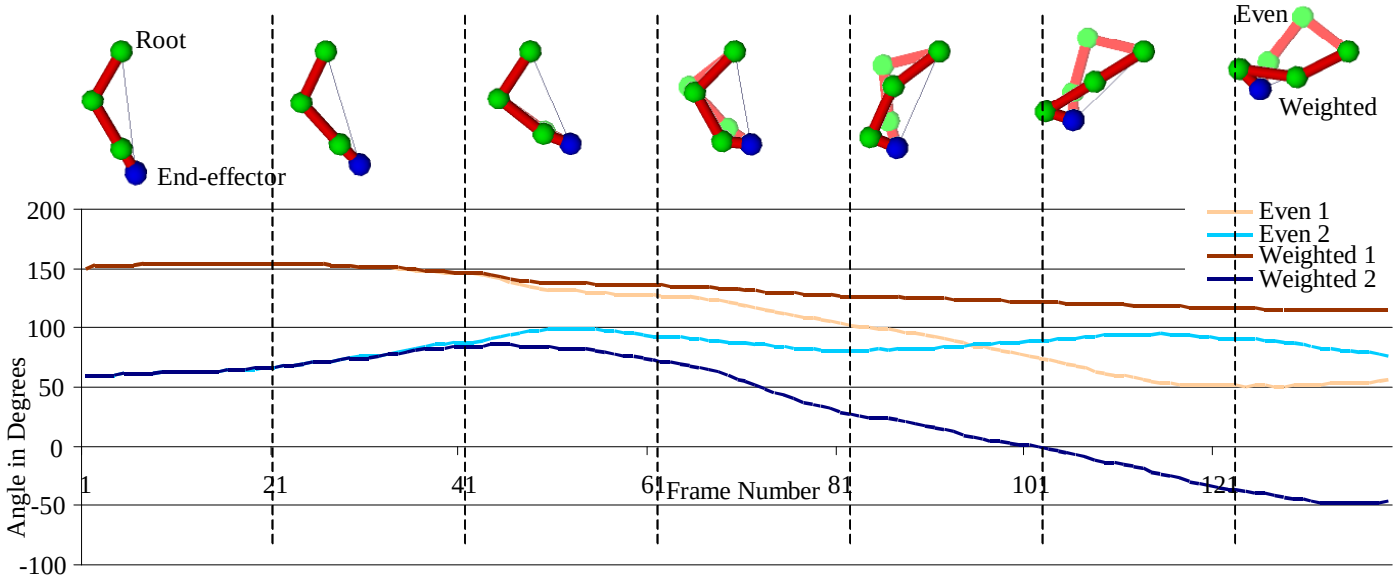


Fig. 1.4: Application of weighted IK chains on a simple articulated structure. Top: Comparison of even (lighter colour chain) and weighted (darker colour chain) distribution update of angles – the root node angle has a reduced weighting value over the rest of the chain. Bottom: Graph of the first two angles in the IK chain working from the root node outwards.

determined by the Control Module. Although this technique can be applied to a variety of different motions, we will demonstrate how the method lends itself to individualisation where limb masses/muscle tone can be taken into account to determine the weighting values. As an additional effect of individualisation, our technique shows good results when applied to simulating injuries as we demonstrate in the next section.

For the subtle changes involved in individualising a character performing a normal motion, we change the weighting parameters only slightly. This has the effect of simulating limb build within the model. For example, large limbs with low muscle tone would have low weights to simulate a sluggish movement while muscular limbs of the same size would have higher weightings to account for the strength of the muscle.

In order to simulate injuries, as well as adjusting the control parameters, we stiffen up the corresponding limb by decreasing the weighting value associated with it. This reflects the fact that the character changes the movement in the part of their body where a restriction is introduced by the infliction or in order to reduce the resulting pain that would result from using the limb in normal motion.

The results of applying different weighting and control parameters to a single base motion are discussed and illustrated in the next section.

IV. RESULTS & DISCUSSION

To illustrate our technique of applying individualisation characteristics in real-time to characters based on motion capture data, we produced a range of different motions by changing only the parameterisation that is determined by the Control Module. The results are obtained by running *MovingIK SE* on a Pentium 4 1.4GHz with a GeForce2 Ultra graphics card. The demonstration animations are achieved in real time running 4 characters simultaneously in response to the same user input.

Figure 1.5(a)[1] shows how changing the weighting parameters of a character can be used to produce a slight deviation in the normal walking motion and hence result in an individualised motion. The adapted motions of Fig. 1.5(a) are portrayed with the skeleton bodies while the original motion capture data is visible as a stick character to the right of the skeletons. Each of the three skeletons in Fig. 1.5(a) are subject to the same control parameters however the weighting vector applied to the inverse kinematics solver varies over the skeletons. The red skeleton has an evenly weighted distribution, i.e. all the values are 1, whereas the green and blue skeletons have weighting vectors that stiffen the hip and knee joints respectively. In the case of the unevenly weighted skeletons, we have decreased the respective weightings for the joints by 80% and 20% and left the rest of the weighting values the same as for the red skeleton.

From the joint angle graph of Fig 1.5(a), the hip angle for the blue skeleton can still be seen to reach a similar maximum and minimum angular measurement as the evenly distributed red character, however it follows a different path over time to achieve this. The effect of using the weighting reduces the rate of angular change for the knee joint for the blue character and hence the hip angle is changed differently to compensate. In comparison, the green skeleton has a stiffened hip joint therefore, as can be seen from the joint graph of Fig. 1.5(a), the amount of change for this part of the body is much reduced. In this case, extra movement in the knee joint compensates for the reduced angular change that can be seen in the green skeleton's hip.

As the IK chains get close to being completely extended, as it does at the extents of the walking cycle, the blue weighted version takes on a similar configuration to that of the evenly distributed red one. This is because the possible solutions the IK solver can generate are more tightly packed into a smaller spatial configuration area so the results look similar in either case. As you would expect, at the start and end of the walk cycles, the postures of the characters appear a close match.

Despite the solution looking similar at the beginning and end of the cycle for the red and blue skeletons (the green one too is very similar but slightly more divergent from the other two), we argue that the differences during the walking phase are enough to demonstrate an individualisation of the character, which is achieved by purely applying weighting vectors to the character. The end configurations could be further diversified if we were to adjust the control parameterisation and skeletal limb lengths. However, in the results we have tried to keep as many parameters constant as possible to demonstrate the potential of weighted IK chains. Furthermore, our Data and Animation Modules are additional contributing factors to the similar looking configurations at the extremities of a cycle because we have specified how a character lands using a two-stage process as shown in Fig. 1.3, thereby limiting the possible configuration space.

By changing the weighting parameters alone we are able to generate many individual motions. However, we have found that the most natural-looking motions tend to be linked with low variances in the weight vector used. Larger variances in the weight vector lead to noticeable exaggeration in the resulting motion because joint angles are not updated significantly until there is no choice in order to meet an end-effector location. This can be seen by comparing the

[1] Animations of the stills of Fig 1.5 are available at http://www.dcs.shef.ac.uk/~mikem/research/ik.html

green and blue skeletons from Fig. 1.5(a) where the former character has an 80% reduction in its weighting value compared to 20% for the blue character. The motions generated with high-variance weighted vectors could account for normal motion in defined cases however we found it tends to lend itself better to motions that, with a slight adaptation in the other control parameters, simulate the appearance of injuries.

The generation of an injured walking motion is illustrated in Fig. 15(b), with both the use of weighted and even distribution over the IK chains. In the case of each of the skeletons of Fig. 1.5(b), the weighting parameters are similar to that used in Fig. 1.5(a) however the weights have only been applied to the left leg which is the one we make limp and the control parameters have been adjusted constantly over the characters. The control parameters are adjusted for the left stride in order to decrease the maximum flight height by 50%, reduce the stride length by 50% and increase the speed with which the stride is undertaken by 30%.

Comparing the red skeleton of Fig. 1.5(a) and Fig. 1.5(b) it is clear from the motion trails that simply adjusting the control parameters is enough to visually change the appearance of the walking motion. This is most visually apparent when comparing the motion trails for the limping red character's feet. Here the left hand side trail barely skims over the ground whereas the right hand side trail contains much more clearance. Furthermore, the trail for the right foot is much smoother and travels further per stride than the limping left foot; a trait that can be seen in all of the limping skeletons of Fig. 1.5(b). An additional visual effect that is not demonstrated in the stills of Fig. 1.5(b) is that the speed with which the stride cycle is undertaken is faster for the injured leg than for the normal walking motion.

As illustrated, by only adjusting the control parameters of the walking motion we can produce a limping motion. However the realism can be enhanced by additionally adjusting the weighting parameters. Similar to the weightings we applied to the normal walking motion, we have applied weighting parameters to the green skeleton to stiffen the left hip joint while the blue skeleton's left knee joint is made stiffer via the weighting values. As the joint angle graphs of Fig. 1.5(b) illustrates, the effect of applying these weightings are to noticeably reduce the amount of movement in the limb compared to the evenly distributed limp motion. This is most noticeable for the hip joint of the green skeleton because it is this angle that is graphed.

As was the case for the normal working motions, the effect of stiffening a joint is to make the remaining angles move more to compensate. This translates into the ability to identify which part of the leg is suffering from the injury. For example, the weighting vector used to simulate the motion of the blue skeleton is tailored to produce an animation that depicts a knee injury. However when we reset the weight values and decrease the weight value associated with the hip joint, we are able to simulate a hip injury as with the green skeleton.

The injury position is achieved by maintaining the control parameters, which like the basic process of individualisation, demonstrates the usefulness of the weighting values in generating subtle differences between base motions thereby customising the resulting motion for a specific stylisation. This makes it possible to determine where the injury is being simulated along the leg.

As the results demonstrate, the additional factor of weighted IK chains provides a good level of differentiation between the changes in joint angles within the character which visually introduces subtle changes for motions that have the same control parameters. This allows us to spawn many motions, each individualised towards a specific character's attributes, at no extra computational cost to the core IK algorithm.

V. CONCLUSIONS & FUTURE WORK

The use of real-time inverse kinematics to adapt existing motion-captured animation has the primary advantage of reducing visual artefacts associated with such animations, i.e. the motion is successfully retargeted to the new character and environment. Through the use of weighted IK chains, we have demonstrated an enhancement to the technique that produces richer visual realism at no extra computational cost. Using weighting values, we have shown that it is possible to take a single motion-captured animation and to adjust the motion to different characters, thereby demonstrating a computationally-cheap mechanism for producing new retargeted and individualised character animations from a single motion-captured data file. Taking the technique a step further, we have further shown how the same base representation can be adapted to simulate injury stylisation by adding in discrete visual differences.

From the results, we have found that weighting vectors that have small variance values over their elements produce normal but subtly different motions suitable to the individualisation of character motions. This level of individualisation allows us to control the relative build of the character by assigning comparatively smaller weights to those joints we would expect to change less than others due to muscle structure. This is due to the direct relationship between the amount of angular change performed during the IK algorithm and the weighting values.

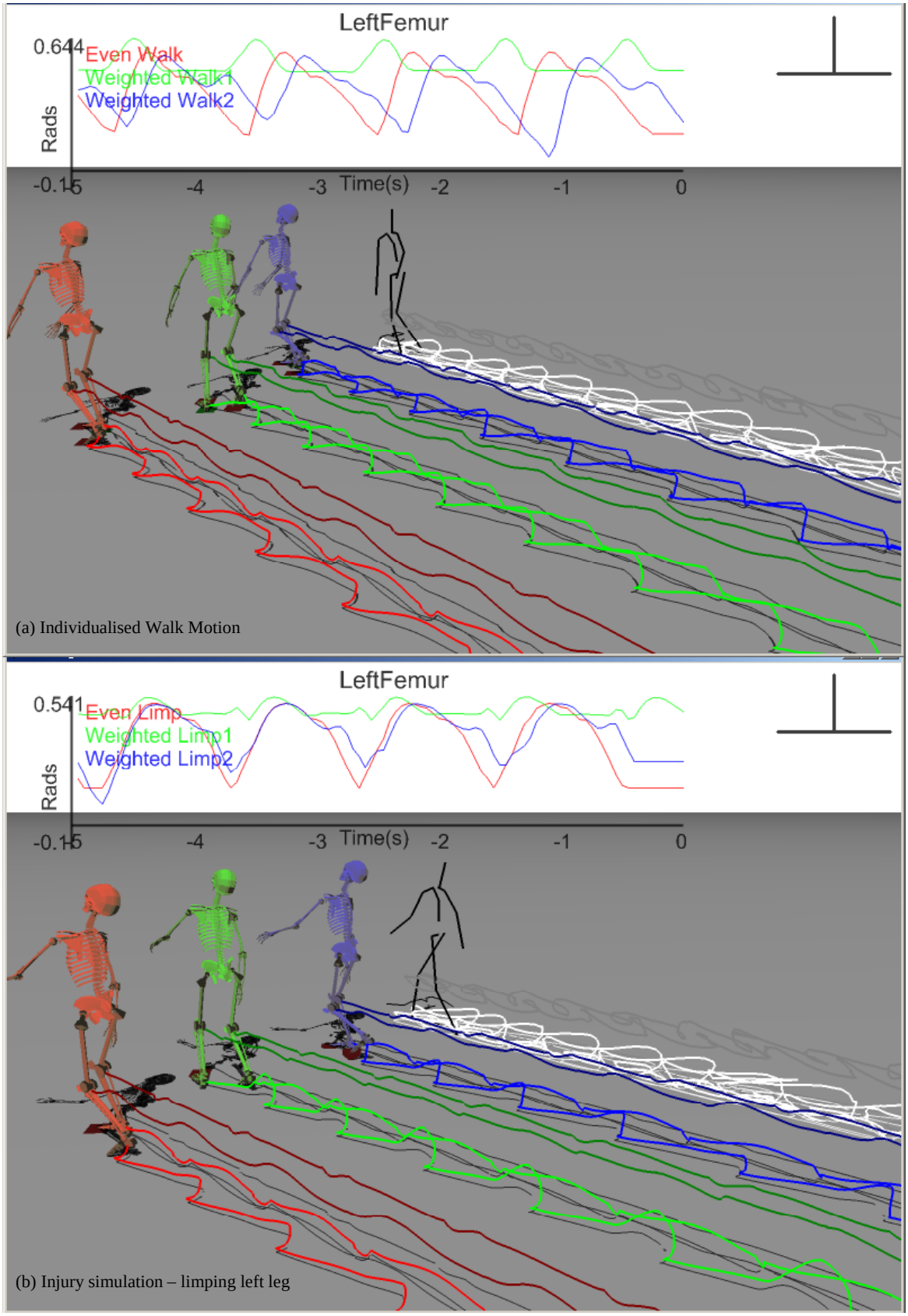


Fig. 1.5: Application of *MovingIK SE* to adapt original motion capture data to (a) individualise and (b) simulate injury to three different characters of different IK weighting vectors.

Going beyond the basic character individualisation, the use of larger variances within the weighting vectors generates exaggerated motions that we have used to depict an injured motion. The simulation of injuries is enhanced through the use of changes in the control parameters and although this has the effect of fundamentally changing the resulting motion, the weighting values give further control in producing a good-looking motion.

We have demonstrated this technique specifically on character gaits. However the idea of adapting the IK result based on weighted chains can apply to any form of posturing using IK. At the heart of this technique, the effect of applying weighting values within the IK chains is to directly affect the rate of change in joint angles. This is a mathematical adjustment on the IK solver itself therefore anything that makes use of the algorithm can utilise this work. Turning to the field of character animation, weighted IK has most potential where computational costs need to be kept minimal but enhanced realism is desirable in the resulting motions.

The next application of this technique is to posture the upper body limbs where it would be reasonable to assume that the same arguments we have presented to demonstrate the application on the legs would also hold for the arms. The application of this algorithm to the upper body would probably produce a much more varied visual result than with the legs because of the increased number of DOFs available to manipulate with the algorithm. An extended area of application that this algorithm would be well suited to is that of performing real-time full body motion retargeting and individualisation.

We acknowledge that this technique will not produce individualisation to a level of realism that dynamics-based techniques can, however we propose that this technique can give a good approximation to the desired results whilst being computational cheaper. Whilst our technique, like any IK solution, is more computationally expensive than directly applying an unadapted, pre-scripted motion to a character, its advantages, namely individualisation and stylisation, are certainly worth appreciating.

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