INSTYTUT BADAŃ SYSTEMOWYCH
POLSKIEJ AKADEMII NAUK

ANALIZA SYSTEMOWA W FINANSACH I ZARZĄDZANIU

Wybrane problemy

Tom 4

Pod redakcją
Jerzego HOŁUBCA

Warszawa 2002

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METHODS FOR AUTOMATION OF HUMAN MOTION MODELING

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Automatic synthesis of character animation promises to put the power of professional animators in the hands of everyday would-be filmmakers, and to enable rich behaviors and personalities in 3D virtual worlds. This goal has many difficult sub problems, including how to generate primitive motion for any class of action (run, jump, sigh, etc.), satisfying any goals and in any style (e.g. sad, hurried, etc.). Other problem is how to parameterize these actions at a high level while allowing detailed modifications to the result, and how to combine the primitive motions to create coherent sequences and combinations of actions. This article concerns essential, practical problem of automatic animation human-like figures with the support of informatics technologies connected with motion capture domain. Up to now, experiments in systems of this kind, appears not to be too adequate to needs. In this situation, we had been faced with the necessity of creating new methods for supporting process strictly connected with creation of animated forms. In this paper, we present overview of existing methods and proposal of our approach based on motion transformation for creating animation from motion capture sequences.

Key words: motion capture, computer animation, motion models, machine learning

1. Introduction

Current computer technology has reached a level that allows a team of professionals to create virtually any special effect, digital character, or virtual world they can imagine. In particular, the massive success of movies such as *Toy Story* (1995) and *Shreck* (2001) demonstrates that we can create, animate, and render believable digital characters that fascinate an audience throughout a feature-length film. However, the effort and skill required to do so are immense, requiring thousands of person-hours from artists, animators, and engineers.

Now that we have the technology to make it possible to bring digital characters to life, the next technological frontier is making the process easier. In this paper we present summary of existing methods for motion creation. Against the background of existing methods we give an idea about our approach that focuses on simplifying the process of animating digital characters. The difficulty of character animation stems from the amount of specification required to make characters move - the skeletal pose alone of a humanoid character (excluding hands and face) requires 50 to 60 scalar values. The second reason is difficulty in deep understanding of the way people and animals move. This is necessary to create animation specifications that result in pleasing, believable motions.

Graphics researchers have borrowed, adapted, or developed many techniques that try to ease above difficulties by either reducing or abstracting the specification required to pose a character, or by encapsulating physical laws of motion or other knowledge into algorithms. For instance, *inverse kinematics* (IK) abstracts the specification needed for posing, by allowing the animator to place constraints on a pose (such as "the foot goes here and the hand goes over there") and relying on the computer to figure out what combinations of the 50 or so skeletal joint angles will satisfy the constraints [2][13]. IK does not, however, help much at making characters move believably, since it is still entirely up to the animator to determine where the foot should move and how quickly it should get there.

Other methods [5][6][10] attack the ambitious goal of *automatic motion synthesis*, in which the computer generates the entire animation from a high-level specification, such as a director might give to actors. Any such approach must provide the computer with some means of automatically choosing natural looking, believable motions from among all the possible motions that satisfy the high-level description. Most automatic approaches guide the computer with physical laws (such as Newton's laws) and dynamics, because all motions that real people and animals perform conform to physical laws, and because physics is straightforward to express in digital form.

These and other, related approaches are potentially powerful, but share several limitations. First, they tend to be very difficult to program, and often do not generalize either to complicated characters or diverse actions. Second, they are extremely computationally expensive, and thus make iterative refinement of an animation difficult, and real-time response is out of the question. Lastly, and in our reasoning most limiting, is the adherence to strict physical realism: animators routinely violate physics in order to create more powerful personalities and draw the viewer's attention.

The rest of this article is organized as follows. In the 2 section will be presented review of methods for motion creation. Third section will cover interactive motion editing with constraints. Fourth section will refer to motion editing with global control. My approach as a part of the TRAF idea will be presented in the fifth section. Discussion and conclusion will be in the last section of the article.

2. Related work

2.1. Limitations of the traditional animation

Motion control of articulated figures such as humans has been a challenging task in computer animation. Using traditional key framing, it is relatively simple to define and modify the motion of rigid objects through translational and rotational trajectory curves. However, manipulating and coordinating the limbs of an articulated figure via key frames or the spline curves they define is a complex task that draws on highly developed human skills. More general, global control of the character of an animated motion would be useful in fine tuning key framed sequences. Much of recent research in motion control of articulated figures has been directed towards reducing the amount of motion specification to simplify the task of the animator. The idea is to build some knowledge about motion and the articulated structure into the system so that it can execute certain aspects of movement autonomously. This has lead to the development of higher level control schemes where the knowledge is frequently specified in terms of rules, and physics-based modeling techniques in which knowledge is embedded in the equations of motion constraints and possibly an optimization expression. Both approaches often suffer from lack of interactivity: they do not always produce the motion, which the animator had in mind, and complex models have a slow interactive cycle. To increase the expressive power of such models, more control parameters can be introduced [1][7][10][17][22].

2.2. Motion capture for realistic animation

An alternative method to obtain movements of articulated figures is motion capture where the motion is captured from live subjects. Systems for real-time 3D motion capture have recently become commercially available. These systems hold promise as a means of producing highly realistic human figure animation with more ease and efficiency than traditional techniques allow. Motion capture can be used to create custom animation, or to create libraries of reusable clip-motion. Clip-motion libraries could facilitate conventional animation, or serve as databases for on-the-fly assembly of animation in interactive systems. Although a variety of technologies have been developed to fairly reliably measure motion capture data, the computer graphics literature makes scant mention of editing techniques for recorded motion. In the absence of effective editing tools, a recorded movement that is not quite "right" requires the whole data capture process to be repeated. Therefore, it is desirable to develop tools that make it easy to reuse and adapt existing motion data [7][10].

2.3. Motion editing

The ability to edit captured motion is vitally important. Custom animation must be tweaked or adjusted to eliminate artifacts, to achieve an accurate spatial and temporal match to the computer generated environment, or to overcome the spatial constraints of motion capture studios. To reuse clip motion we must to be able to freely alter the geometry and the timing. To be useful, editing should be much easier than animation from scratch, and should preserve the quality and naturalness of the original motion. Much of the recent research in motion control has been devoted to developing various kinds of editing tools to produce a convincing motion from prerecorded motion clips. To reuse motion-captured data, animators often adapt them to a different character [11] or to a different environment to compensate for geometric variations [7][22]. Animators also combine two motion clips in such a way that the end of one motion is seamlessly connected to the start of the other. There also has been the research about how to represent and apply the emotion or the style of the original motion to another [19]. Subsequently, we will survey the motion editing techniques developed so far. This will be used to indicate where to situate our approach presented in section 5. We can categorize the motion techniques as follows:

- Interactive motion editing with constraints
- Motion editing with global controls

In section 3, we will review interactive animation tools for constraints-based motion editing and in section 4, we will review an alternative approach is to provide more global animation controls. This review can help the reader to find the information about modern motion editing techniques that are not presented by any of books yet.

3. Interactive motion editing with constraints

Much recent effort has addressed the problem of editing and reuse of existing animation. A common approach is to provide interactive animation tools for motion editing, with the goal of capturing the style of the existing motion, while editing the content. Gleicher [10] provides a low-level interactive motion editing tool that searches for a new motion that meets some new constraints while minimizing the distance to the old motion. A related optimization method is also used to adapt a motion to new characters [11]. Lee et al. provide an interactive multiresolution motion editor for fast, fine-scale control of the motion [16]. Most editing systems produce results that may violate the laws of mechanics. Popovic and Witkin [17] describe a method for editing motion in a reduced-dimensionality space in order to edit motions while maintaining physical validity. Such a method would be a useful complement to our techniques.

3.1. Spacetime constraints

Gleicher [10] suggested a method for editing a pre-existing motion such that it meets new needs yet preserves as much of the original quality as possible. His approach enables the user to interactively position characters using direct manipulation. He used spacetime constraints, which consider the entire motion simultaneously. This method enables the user to specify constraints over the whole motion and use a solver to compute the "best" motion that meets these requirements. Like more traditional key frame and inverse kinematics methods, the user makes adjustments to an animated character with direct manipulation, for example pulling on a character's hand to reposition it. However, to achieve these new positions, the animation system makes adjustments that attempt to preserve the original motion.

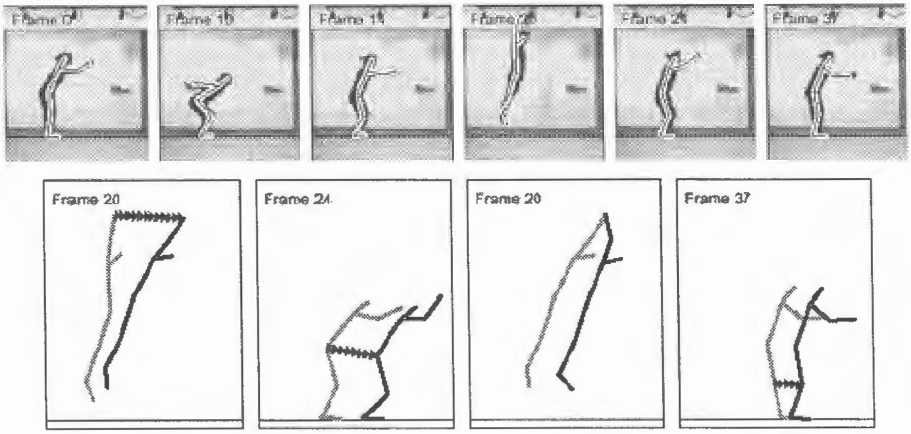

Figure 1. Editing rotoscoped jumping motion

For example, in figure 1, a user pulled the hand at frame 20, the pelvis at frame 24, and the knee at frame 37. At frame 20, the hand constraint is maintained while all the other parts of the body moved to satisfy the constraints. Like other spacetime constraint methods, their system considers the entire motion in making changes. Unlike the previous spacetime systems, they solve the numerical constraint problems fast enough to provide direct manipulation dragging. To achieve this new style of motion editing, they devised a constraint formulation that is rich enough to be effective, yet simple enough to permit rapid solution and they introduced fast methods for solving these constraint problems. Using this method, it is very difficult to encode the style of motion mathematically, in other words it is almost impossible to specify meaningful attributes such as "gracefully" or even "like Charlie Chaplin". A more serious omission is the lack of Newton's laws in their system. The physics constraints have structure that appears to make solution of the optimization problems much more difficult.

3.2. Retargeting motion to new characters

Gleicher [11] suggested a technique for retargeting motion that is the problem of adapting an animated motion from one character to another. His focus is on adapting the motion of one articulated figure to another figure with identical structure but different segment lengths. His method creates adaptations that preserve desirable qualities of the original motion.

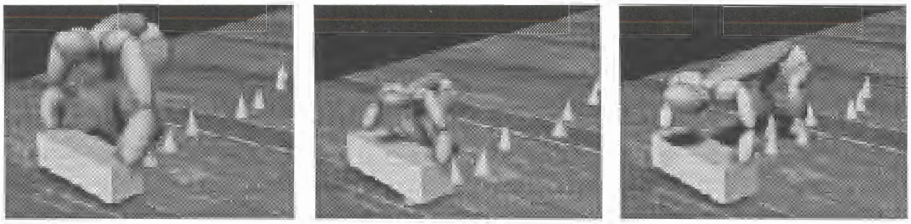

Figure 2. Example of retargeting motion to new characters

He identifies specific features of the motion as constraints that must be maintained. Constraints are the primary tool used to identify features of the original motion that must be present in the retargeted result. Specification of these constraints typically involves only a small amount of work in comparison with the tasks of creating the characters and motions. Constraints are generally defined once for each motion, and this one set of constraints is used for any retargeting. Since there are typically many possible motions that satisfy the constraints, they use an objective function to select the best choice. A simple objective could be "minimize the amount of noticeable change". In figure 2, differently sized characters pick up an object. Their positions are determined by the position of the object. The left shows the original actor, the center shows a figure 60 % as large and the right shows a figure with extremely short legs and arms and an extremely long body. Their approach makes many sacrifices to achieve practicality. They tell their solver little about the original motion or general motion properties, and their choice of the mathematical problem is heavily influenced by what can be solved efficiently. Some of the problems they see are artifacts of the specific simple objective they have chosen and their reliance on simple frequency limits on the adaptations. Other problems occur because they have no guarantees on the many properties they do not explicitly model in their constraints and objective. For instance, their lack of physics constraints can lead to unrealistic situations.

3.3. A hierarchical approach to interactive motion editing

Lee et al. [16] suggested a technique for adapting existing motion of a human-like character to have the desired features that are specified by a set of constraints. This problem can be typically formulated as a spacetime constraint problem. Their approach combines a hierarchical curve fitting technique with a new inverse kinematics solver. They employed the multilevel B-spline fitting technique. They also present an efficient inverse kinematics algorithm, which is used in conjunction with the fitting technique. Using the kinematics solver, they can adjust the configuration of an articulated figure to meet the constraints in each frame. Through the fitting technique, the motion displacement of every joint at each constrained frame is interpolated and thus smoothly propagated to frames. They are able to adaptively add motion details to satisfy the constraints within a specified tolerance by adopting a multilevel B-spline representation. The performance of their system is further enhanced by the new inverse kinematics solver. They devised a closed form solution to compute the joint angles of a limb linkage. This method greatly reduces the burden of a numerical optimization to find the solutions for full degrees of freedom of a human-like articulated figure. Their approach differs from the work of Gleicher who addressed the same problem. Gleicher provided a unified approach to fuse both relationships into a very large nonlinear optimization problem, which is cumbersome to handle. Instead, Lee et al. decouple the problem into manageable sub problems each of which can be solved very efficiently.

3.4. Physically based motion transformation

Popovic and Witkin [17] introduced a novel algorithm for transforming character animation sequences that preserves essential physical properties of motion. By using the spacetime constraints dynamics formulation their algorithm maintains realism of the original motion sequence without sacrificing full user control of the editing process. In contrast to most physically based animation techniques that synthesize motion from scratch, they take the approach of motion transformation as the underlying paradigm for generating computer animations. In doing so, they combine the expressive richness of an input animation sequence with the controllability of spacetime optimization to create a wide range of realistic character animations. The spacetime dynamics formulation also allows editing of intuitive, high-level motion concepts such as the time and placement of footprints, length and mass of various extremities, number of body joints and gravity. At its core, their algorithm uses spacetime optimization because the spacetime formulation maintains the dynamic integrity of motion and provides intuitive motion control. Because such methods have not been shown to be feasible for human motion models, they must also find a way to simplify the character model.

The main shortcoming of their approach is that large portions of the motion fitting algorithm stage are performed manually. They have found the simplification process quite intuitive. The simplification is performed only once per input motion sequence, so the effort spent by the motion library creator is amortized over the large number of possible transformed animation sequences. Nevertheless, automating this manual decision-making process would enable on-the-fly construction of a physically based spacetime formulation from an input animation.

4. Motion editing with global controls

Researchers tried to edit motion sequences with global controls. Some of them used signal processing techniques or frequency domain techniques to represent and apply the emotion or the style of the original motion. Signal processing systems, such as described by Bruderlin and Williams [7] and Unuma et al. [21], provide frequency-domain controls for editing the style of a motion. Witkin and Popovic [22] blend between existing motions to provide a combination of motion styles. Rose et al. [5] use radial basis functions to interpolate between and extrapolate around a set of aligned and labeled example motions, and then use kinematic solvers to smoothly string together these motions. Brand and Hertzmann [6] suggested style machines, which generate stylistic motion by learning motion patterns from a highly varied set of motion, capture sequences.

4.1. Signal processing techniques

Bruderlin and Williams [7] applied techniques from image and signal processing domain to designing, modifying, and adapting animated motion. Using their method, existing motions can be modified and combined interactively at a higher level of abstraction. They applied the principles of image multiresolution filtering to motion parameters of an articulated figure, motivated by the following intuition: low frequencies contain general, gross motion patterns, whereas high frequencies contain detail, subtleties, and most of the noise. An application of motion multiresolution filtering is illustrated in figure 3. Displayed like an equalizer in an audio amplifier, this is a kind of graphic equalizer for motion, where the amplitude (gain) of each frequency band can be individually adjusted via a slider before summing all the bands together again to obtain the final motion.

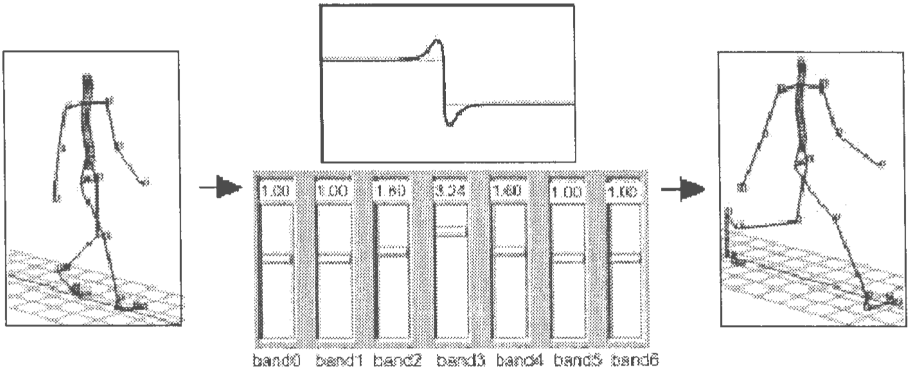

Figure 3. Adjusting gains of bands for joint positions

4.2. Fourier principles for emotion-based human figure animation

Unuma et al. [21] described the method for modeling human figure locomotion with emotions. They used Fourier series expansions of experimental data of actual human behaviors to interpolate or extrapolate the human locomotion. For example, the transition from a walk to a run is smoothly and realistically performed by the method. Moreover, an individual's character or mood, appearing during the human behaviors, is also extracted by the method. For example, the method gets "briskness" from the experimental data for a "normal" walk and a "brisk" walk. The "brisk" run is generated by the method, using another Fourier expansion of the measured data of running. The superposition of these human behaviors is shown as an efficient technique for generating rich variations of human locomotion. In addition, step-length, speed, and hip position during the locomotion are also modeled, and then interactively controlled to get a desired animation. Based on the Fourier series expansion of the original measured data, a functional model is defined for generating a rich variation of movements, far from the original. In making a human figure animation, however, they must treat not only the emotional aspect but also the kinematic aspect. Therefore, the functional model of their method is further extended to provide intuitive parameters for simultaneously controlling emotional and kinematic human locomotion, where the kinematic control, for example, prescribe speed and step-length of the human figure model. However, their method is not invertible. This means that the transition from running to walking by the method is unnatural, while the realistic transition from walking to running is made by the method. The very limitation of the superposition technique will be clarified under more explicit formulation.

4.3 Motion warping and blending

Witkin and Popovic [22] introduced a simple technique for editing captured or key framed animation based on warping of the motion parameter curves. The animator interactively defines a set of key frame like constraints which are used to derive a smooth deformation that preserves the fine structure of the original motion. Motion clips are combined by overlapping and blending of the parameter curves. They showed that whole families of realistic motions can be derived from a single captured motion sequence using only a few key frames to specify the motion warp.

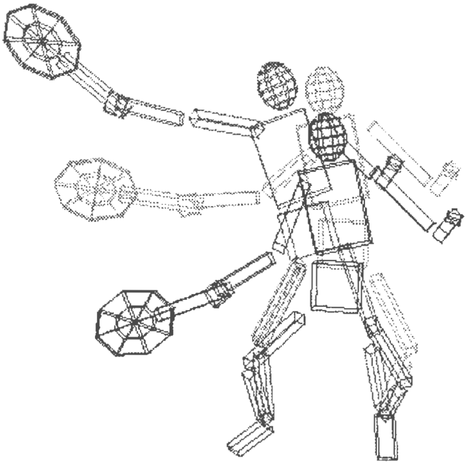

Figure 4. Motion warping

Their method is similar to that of conventional key framing, in that the animator interactively modifies the pose at selected frames. The main contribution of their research is to introduce motion warping as a means of editing captured motion and to demonstrate that even very complex motions such as a human walk or a tennis swing can be radically reshaped using just a few key frames without losing their realistic appearance. In figure 4, we can see a frame from a captured motion sequence of a tennis forehand shot, and the corresponding frames from two warped sequences. Only a single key frame at the moment of impact was required to produce the warped sequences.

To create transitions between clips, they perform motion blends using a technique in which the motion to be joined are overlapped, with one or more critical correspondence points identified. The combined motion is generated by time warping the constituent motions to align the correspondence points, then blending using time-dependent weights. A key advantage of motion warping is that it fits well into the familiar key frame animation paradigm, allowing a wide range of existing tools, techniques, and skills to be brought to bear. On the other hand, motion warping shares some limitations of standard key framing, for example the difficulty of enforcing geometric constraints between keys. Constraints techniques applicable to conventional key framing can be applied to motion warping as well. A further limitation is that motion warping is a purely geometric technique, not based on any deep understand of the motion's structure. Consequently, as with analogous image morphing techniques, extreme warps are prone to look distorted and unnatural. A physically based technique might overcome this limitation.

4.4. Multidimensional motion interpolation

Rose et al. [5] introduced methods and data structures used to leverage motion sequences of complex linked figures. They developed a technique for interpolating between example motions derived from motion capture or produced through traditional animation tools. These motions can be characterized by emotional expressiveness or control behaviors such as turning or going uphill or downhill. They call such parameterized motions “verbs” and the parameters that control them “adverbs.” Verbs can be combined with other verbs to form a “verb graph” with smooth transitions between them, allowing an animated figure to exhibit a substantial repertoire of expressive behaviors. A combination of radial basis functions and low order polynomials is used to create the interpolation space between example motions. Inverse kinematic constraints are used to enhance the interpolations in order to avoid, for example, the feet slipping on the floor during a support phase of a walk cycle. Once the verbs and verb graph have been constructed, adverbs can be modified in real-time providing interactive or programmatic control over the characters' actions. This allows the creation of autonomous characters in a virtual environment that show complex and subtle behavior.

4.5. Stylistic motion synthesis

Brand and Herzmann [6] approached the problem of stylistic motion synthesis by learning motion patterns from a highly varied set of motion capture sequences. Each sequence may have a distinct choreography, performed in a distinct style. Learning identifies common choreographic elements across sequences, the different styles in which each element is performed, and a small number of stylistic degrees of freedom which span the many variations in the dataset. The learned model can synthesize novel motion data in any interpolation or extrapolation of styles. For example, it can convert novice ballet motions into the more graceful modern dance of an expert. The model can also be driven by video, by script, or even by noise to generate new choreography and synthesize virtual motion-capture in many styles.

For the purpose, they introduced the style machine - a statistical model that can generate new motion sequences in a broad range of styles, just by adjusting a small number of stylistic knobs (parameters). They seek a model of human motion from which they can generate novel choreography in a variety of styles. Rather than attempt to engineer such a model, they attempted to learn it by using *unsupervised learning* technique.

They used the Hidden Markov Model (HMM) to learn the choreography and the style of motion data. A HMM is a probabilistic finite-state machine consisting of a set of discrete states, state-to-state transition probabilities, and state-to-signal emission probabilities to learn. They added to the HMM a multidimensional style variable v that can be used to vary its parameters, and call the result a *stylistic* HMM (SHMM). Using SHMM, they separated structure, style and accidental properties in a dataset by minimizing entropies in the SHMM and finally they can generate new choreographies with various styles.

5. The TRAF idea

Previous approaches to automatic motion synthesis are limited to producing motion in styles that can be described mathematically. Our research group developed methods useful for automatic character animation that combines motion transformation techniques with motion sequences extracted from *motion capture* files. I proposed in [25] a new synthesis method using motion transformations based on *measure of discrepancy*. This idea was foundation for development of the system TRAF[1], which

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[1] **T**ool for Creation **R**ealistic **A**nimation of Human-like **F**igures

automatically synthesizes motion in any style for which we possess a few example motions [3][8][20][25].

5.1. Motivation & goals

It is clear that there are many benefits to be gained from making believable character animation easier to create. My approach is motivated primarily by three specific applications:

- **Autonomy from automation animation**. Computers let animators create motion. Methods for automation of digital character creating are sometimes effective but very inconvenient. In particular, user can define how to create motion by definition of several key frames. This sort of work calls for a lot of patience from animator, because he cannot watch the results at once. Using *motion capture* sequences and interactively collaborating with program during the process of motion creation, user can easily satisfy the desire and change it at any moment.

- **Universal animation**. Human being is able to understand more effective when information, which he gains, is presented by set of pictures rather than audio information. Using animations for exchange information will simplify communicating process.

- **Internet based motion studios**. Nowadays is very easy to imagine the situation where exists one enormous multimedia database in where primitive motions are stored. Animators from all over the word are able to create specific animations taking advantage of primitive motions from the virtual motion library. In this situation, it is necessary to create application that will help animator simply create dream-motion with effectively usage of primitive motions.

This approach consists of tree main parts. **First**, we developed the *motion models* - new abstractions that are useful for motion creation process. Thanks to motion models mechanism we can easily and more effective choose primitive motions from the multimedia database. It is also helpful in the process of motion synthesis. On the base motion models hierarchy we can faster and more effective solve the problem defined by user starting from general motion formulation and descending to particulars. **Second**, I developed algorithms for combining the primitive motions using motion models [25]. I presented methods for calculating transition between two primitive motions, utilizing information gleaned from motions database and new metrics. This metric is a special *measure of discrepancy* between two motion sequences, developed especially for making distinctions between two motions. I also presented methods for motion blending, editing, and filling the gaps between two motion sequences [25]. One of the most important problems is selection of the most appropriate method for rotation interpolation. This is fundamental problem during motion synthesis. **Third**, I developed algorithm for motion fitting [25]. It is very important to create the possibility of motion bending. Possessor of the tool can twist straight motion as one wish. This algorithm uses *"step formula"*, so it may be applied only to these motions where steps exist (run, walk, jog, etc.).

5.2. Introduction to the TRAF system

TRAF system was designed as a tool to create animations of realistic human-like figures. This system is connected with modern animation systems, based on *motion capture* technology. Distinguishing novelty in this project is reusing of existing and properly converted motion sequences. In case of repeatedly using this system, TRAF was equipped in multimedia database gathering converted animations. This is a very complicated problem, process of data collecting and making use of the system to create animation. Therefore the problem cannot be considered as a whole. The fundamental establishment of the system is producing animation with a special emphasis on the motion reality. There are many mechanisms in existing *motion capture* sequences that enable to mark out specific fragments. After suitable ordering these fragments in system database, they can be useful to create a quite new motion. To create such a motion it is necessary to deliver adequate methods, tools and to assure user communication. This short introduction let us to separate four functional blocks from the system, as is shown in figure 5. TRAF modules consist of two groups, because of functionality: Motion Analysis and Motion Synthesis [25].

First functional group consists of two independent parts: Analysis Unit and Database Unit. Motion sequences get from outside in the form of motion capture data into Analysis Module. This part of TRAF is responsible for analyses of motion data that get to the system [20]. It is based on proper division of *motion capture* sequences into smaller parts - *primitive motions*. Next, it is required to normalize loaded data. This process consists of normalization of skeleton shape and motion data. After normalization data are analyzed for the sake of primitive motion's contents. Approximated models and simple motions are data that Analysis Unit transmits into Database Unit. The main function of DBU is operating of the multimedia database that gathers motions used in animation process in the TRAF system [3]. On the grounds of intercepted questions DBU realizes passable database

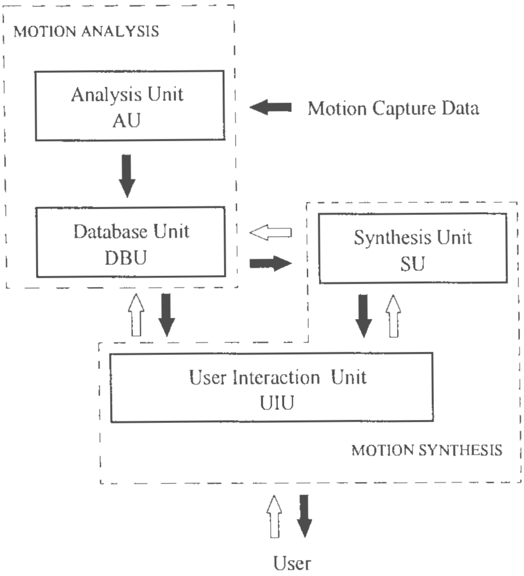

Figure 5. The structure of the TRAF system with separated functional blocks. Arrows on the picture indicate the data flow in the system

searching operations and gives back results these operations to other modules. There is a special method of database organization; therefore DBU takes over part of complex problem creating of automatic animation. It facilitates the control of used solutions and facilitates progressively adding functions to realize by the system. Elementary motions delivered to database from Analysis Unit, are in DBU divided in groups in accordance of specially defined similarity measure of motion characters. There are assigned motion character standards for individual groups of movements that are represented as models of parametric group (so-called general motion models). Between general models and primitive motions there are established adequate relations, which enable later reconstruction of obtained division. New elementary motion loaded into database are classified into equivalent groups and “bounded” in relation with passable general models.

Second functional group includes Synthesis Unit [25] and User Interaction Unit [8]. The information flow is in this group more developed. There is also need to cooperate with DBU, as a motion data information store. In the process of making animation the user defines the task of motion forming by UIU for the TRAF system. User Interaction Module creates restrictions on the basis of data from controlling points and behaviors. User has the possibility to freely watching presenting scene; he can add and remove elements of this scene and change its parameters. Task defined by user to create motion is headed for Synthesis Unit. The basis objective of this module is trying to make motion on the grounds of received restriction collection. In this case it is necessary to cooperate with other units of the system. Task solution is given by processing and transferring information between UIU and DBU. To solve problem it is necessary to do constraints analysis and on its basis define farther steps of procedure algorithm. Each task is solved multistage by Synthesis Unit setting apart from restriction set, single problems (time, pose or behavior) [25]. Then every task is individually examined but taking into account parameter of neighboring one. Because UIU defines task as a collection of restrictions it is needed put this type of collection to the Restriction Analysis and received collection of single tasks transform into limits in motion models. Those limits are sent as an ask about motion models to DBU. Each single task has particular priority for the sake of restriction type, so we get ordered sequence of elementary problems and there is built a solution from these tasks. There is a possibility to automation of solving problems and finding partial answer in case if there is not possible to find solution for all basic tasks.

6. Discussion and conclusion

Much recent effort has addressed the problem of editing and reuse of existing animation. In this paper, we surveyed some of recent motion editing researches. We divided the approaches into two categories, one is interactive motion editing with constraints and the other is motion editing with global controls.

The researches of interactive motion editing with constraints provide interactive animation tools for motion editing, with the goal of keep the characteristics of the original motion, while editing the content. They provide a low-level interactive motion-editing tool that searches for a new motion that meets some new constraints while minimizing the distance to the old motion.

An alternative approach, researches on the motion editing with global control is to provide more global animation controls. Signal processing systems and frequency domain techniques are used in editing the characteristics or styles of a motion. They are also used to blend between existing motions to provide a combination of motion styles. There was a research on a stylistic motion synthesis by learning motion patterns from a highly varied set of motion capture sequences. They developed Stylistic

Hidden Markov Models to represent the structure and the style of the motion capture data.

One of the main purposes of motion control and motion editing researches is to reduce the specifications of the motion, which the user has to give, while not losing the control of the motion. There exists a trade-off between the reduction of the specification and the preservation of the control of motion. In order to achieve this purpose the system must have knowledge about the motion and a kind of intelligence, which can replace some of the user's role. The artificial intelligence approaches, such as style machines, must be useful to achieve this purpose.

Creating of motion animations with taking advantage of traditional animation demands of skills to reality observation from animator and competently describing it as a series of pictures. There is difficult to obtain very realistic effects. In this way, so the other method that supports this process is capturing frames from movies. This method is not so good for the contemporary solutions of three dimensional (3D) graphics. In particular, using 3D models and defining equations of motion according to the physical rights gives better results. Neither this nor other existing methods basing only on dynamical equations of motion, let to get full realism of human motion. Reliable movement of animated figures we can obtain by registering of motions from living actors. This method is named *motion capture*. Drawback of this method is that we cannot reuse generated sequence of motion by even small modification of existing motion. This causes difficulties and makes this method less effective and more expensive in motion production. By the same reason there is obvious limitation in the applications using these kinds of motion data. There is a lot of methods developed, which tries to find solution to the problem, it means, how to generate other motion from existing one. These methods focus on modifications of singular motions only.

Fundamental methods presented in this paper are only part of method for creation realistic animations of human-like figures. So that, against the background of existing methods for motion creating, it makes a sense to present full solution as is proposed in the project TRAF, preliminary described in the previous section. Solution given by TRAF system is a specific solution among these proposed at the present time. This approach focuses not only on full realism of created animations but also on automation of motion creating process. Amongst applied techniques for creation animation predominates only one of the aspects. In the systems for building animations automatically typical are used simulations of three-dimensional models, because there is much easier automate this process. Whereas in the systems based on motion capture technology, motions of animated figures are selected manually. Even though we employ automatic choice of motions in order to create longer and more complex animated sequences, this method is restricted to small amount of simply and very specific motions. In the TRAF system among the set of motions is searched some specific common characteristic features. There is similar idea in searching of common motion features in the work [21], based on the Fourier transformations. They are looking for a common nature, there in the groups of motions. Nevertheless in this method finding common features is restricted to the given types of motions but in the TRAF system looking for characteristic features is so-called *unsupervised learning*. It means that the method while looking for the features bases exclusively on data without any directions from user. Most similar in properties to ideas of TRAF system is Brand's and Herzman's approach [6]. They are looking for the patterns in the motion set and next use them to generate any animation. However, specific solutions are different. Brand and Herzman take advantage of probabilistic motion model, which after learning with the help of set of realistic motions is able to absolutely replace *motion capture* data. In case of TRAF system, uniform in respect of feature primitive motions, obtained in the process of longer complex motion segmentation, are divided in groups according to the distinctive features. There is probabilistic description created for every group. In this way, the method helps to link original motion capture data, in contradistinction from the Brands' and Herzmans' technique. Moreover these authors do not focus their attention on the full automation for motion creation, while TRAF system authors going in the opposite direction. There is difficult to say which method is better or attain success, because both of them are still under development.

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