REPORT

Report 12 p., 30 references.

MOTION CAPTURE TECHNOLOGY, 3-D ANIMATION GENERATION, 3-D ANIMATION MODELING, ANIMATION OF WALKING, NEURAL NETWORKS, NEURAL NETWORKS FOR THE ANIMATION.

This report contains the review of the works related to interactive 3-D animation modeling with the usage of motion capture technologies and also the solution review for the inverse kinematics task, which is also related to this work.

The goal of the work is to the review the existing solutions of the virtual animation generation with the usage of motion capture technologies and to emphasis main ideas, pros and cons of these solutions. Complete review of the existing solutions will strictly determine an area to be explored by novel approach, the means, which have already been applied, and their effectiveness.

Various means of the animation generation with applied motion capture techniques, related motion capture tasks and applied neural networks tasks are described in the review. This review illustrates different approaches to the animation generation and accentuates pros and cons of every approach. The review will be applied to formation of the novel approach to this problem’s solution.

CONTENTS

Report plan

1. Introduction – 1 page
2. Contents – 1 page
3. ??A concept of neural network, shortly explained
4. Neural networks in various approaches – a review – 3 pages
5. Proposed approach to our problem. Actuality and novelty - 4 pages

To pay attention to: how many neural networks are needed? A one common network or several networks?

1. Where to use – 1 page
2. What should be improved – variants – 1 page

To pay attention to markerless mocap application – it has became more popular

1. Conclusion – what has been done and developed, where can be used – 1 page
2. Literature list – 3 pages

INTRODUCTION

**It has commonly been assumed, that** animation is an essential aspect of virtual reality systems, which applies 3D models for various tasks: computer games development, movement simulation (sport applications, educational applications and all applications, which have the goal to vizualise something), films and etc. Term “animation” stands for a process of enabling virtual model movements. However, animation, generated by a computer, often seems unnatural. Human eye is accustomed to smooth, soft motions, and this raises a problem of producing a computer algorithm, which generates natural animation for 3D models. **According to recent trends**, this problem can be considered as actual.

An ideal method of animation generation meets all the criteria of simplicity, velocity, controllability, flexibility and ability to adapt to external environmental conditions in order to provide plausible motion, accepted by human perception. When human himself moves, he considers a wide manifold of various parameters: terrain conditions (hills, pits, frissures…), weather conditions (strong wind, rain…). Motion capture technology maps a real movement to digital dataset, according to these parameters. The goal is to produce a reusable tool (or a model) for animation generation.

This research explores a group of approaches to animation generation, which base on data, obtained via motion capture technologies and neural network algorithms. This paper offers a novel approach to animation generation, based on both motion capture and neural networks technologies. This approach offers simple model and rapid frame generation. A model, which is built once, allows to retrieve new frames for the any moment of time fast and doesn’t require continuous complicated calculations. Also there is no necessity for the generation of the new animation by hand with the help of 3-D modeling programs.

Motion capture is a technology for gathering data of real human motion. It can be briefly described as a set of sensors, placed on the body and collecting data while motions are being performed. **However**, raw motion capture data should be properly filtered and cleaned before its direct use. There are only several truthworthy tools, which are capable of motion capture data proper handling, and almost all of them cost much[1]. However, many motion capture databases are available to the public[3]. Despite this fact, motion capture technology **could become more popular within computer games, films and educational applications development in the future**[1].

Neural networks stand to the set of algorithms and mathematical models, which are based on natural brain structure with neurons and connections between them. According to recent reports, neural networks can be applied to various tasks, such as image recognition, natural language processing, and any task, which requires modeling and approximation of different types of functions[29].

The goal of this work is to describe a proposed approach and to review already existing works, which are relative to motion capture with neural networks.

NEURAL NETWORKS

PROPOSED APPROACH

An approach, proposed by this paper, applies a neural network with dynamical activation function to the task of animation frames generation. Dynamical activation function stands for a solver of system of ordinary linear differential equations. It is commonly assumed, that human body joints depend on each other, and articulated skeleton has more than 50 degrees of freedom[13]. That’s why movement functions of body joints can be presented as a system of ODE with non-linear solutions. There is a manifold of various human motion, and statistical models[9, 15, 16] produce only some of them. The most popular are running, walking and matrial arts fighting. A modeling of every possible motion of human skeleton with various statistical model can take a huge amount of time, so there is a need for a system, which will be able to easily adapt to various parameters and produce new motions. A neural network is able to adapt to any parameters (environment, speed and user input), but its architecture needs to be constructed and system should be properly trained. This approach proposes a system of ordinary differential equations as an activation function of the fully connected neural network. Let’s consider

,

,

where is a function of time of every joint of body skeleton, stands for first-order derivative and are neural network’s weights. The neural network, build on this architecture, shown on Figure 1.

The values present joints position in world space. The new values, , obtained as a non-linear solution for system S. Weights are obtained as a result of learning process. Once appropriate weights are found, the neural network is capable to generate a solution, or set of joint functions, which correspond to movement process – running, walking, jumping, climbing, etc. However, it should be considered, that every type of motion corresponds to its own set of weights in neural network. Holden et al[6,8] considered the manifold of weights by changing them on every frame, which can be stand for one or several time steps.

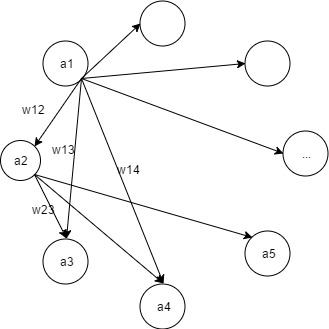


Figure 1. Fully connected neural network.

An animation frame for any sequence of time steps can be generated on demand, after the network has been trained. Movement values , which are used for training, can be obtained from motion capture database. Motion capture frames do not need to be smoothed between each other, as it has been done in some researches[16, 25]. However, the task of various motions frames retrieval should be considered, as the particular set of weights should be obtained for every type of motion. Papers[13, 15] question a retrieval of sensible parts from motion capture dataset, as it is hard to analytically determine the start and the end of particular motion. Müller et al[17] concentrate on consecutive frames retrieval, which produce the same vectors of predefined features. Zhang et al[30] present a frame extraction, based on genetic algorithm, and So et al[24] applies entroby-based function to define a relevance between two frames, e.g. probabilistic relation between two frames. Kadu et al[11] treat one single frame as particular motion. In [13] the break point for division is determined as a sign change of the first derivative of implicit mocap function of time., and in [15] k-means clustering is applied.

FURTHER WORK

However, now neural network does not consider neither velocity parameters nor environmental and user control parameters. This can be corrected by adding neurons for user input, terrain pattern and velocity value.

Some researches are concentrating on simulation of various parts of the body – hands, face [1, 10, 16]. The possibility of neural network fitting to various parts of the body should be questioned. Also system in current stage almost do not take into account physical limitations of real life motions. Multon et al[18] use inverse kinematics with motion capture to pay attention to kinematic constraints of the motion. Neural network fitting to environmental and physical restriction parameters should also be explored. However, motions can be presented not only as digits in coordinate system, but also as foot trajectory, stroboscopic motion (or form-based motion) and other various cues[22]. This motion representation can be used for the terrain and atmosphere fitting of generated motion of animated character.

According to recent researches[3], the markerless motion capture and video motion capture, obtained from several cameras, has become extremely popular. This concept draws away a model of neural network, which takes joint angles as parameters, which can be obtained only from skeletal representation of a motion.

CONCLUSION

LITERATURE AND REFERENCES

1. B.J.H van Basten, S.E.M. Jansen, and I. Karamouzas. Exploiting Motion Capture to Enhance Avoidance Behaviour in Games, The Second International Workshop on Motion in Games.
2. Belanche Muñoz, Lluis. Heterogeneous neural networks: theory and applications.  Universitat Politècnica de Catalunya. Departament de Llenguatges i Sistemes Informàtics (2007).
3. Bradwell, B., Li, B.: A tutorial on motion capture driven character animation. In: *Eight IASTED International Con-ference Visualization, Imaging, and Image Processing.Palma de Mallorca* (2008).
4. Bodenheimer, B., Rose, C., Rosenthal, S., Pella, J. 1997. The Process of Motion Capture: Dealing with data. Computer Simulation and Animation Eurographics, p. 3 - 18.
5. Chaudhari, Gaurav Uday and V, Manohar and Mohanty, Biswajit (2007) Function approximation using back propagation algorithm in artificial neural networks.*BTech thesis.*
6. Daniel Holden, Jun Saito, and Taku Komura. 2016. A deep learning framework for character motion synthesis and editing. *ACM Trans. Graph.* 35, 4, Article 138 (July 2016), 11 pages. DOI: https://doi.org/10.1145/2897824.2925975.
7. Daniel Holden, Jun Saito, Taku Komura, and Thomas Joyce. 2015. Learning motion manifolds with convolutional autoencoders. In SIGGRAPH Asia 2015 Technical Briefs (SA '15). ACM, New York, NY, USA, Article 18 , 4 pages. DOI=http://dx.doi.org/10.1145/2820903.2820918.
8. Daniel Holden, Jun Saito, and Taku Komura. Phase-Functioned Neural Networks for Character Control. ACM Trans. Graph. (July 2017).
9. Jehee Lee, Jinxiang Chai, Paul S. A. Reitsma, Jessica K. Hodgins, and Nancy S. Pollard. 2002. Interactive control of avatars animated with human motion data. ACM Trans. Graph. 21, 3 (July 2002), 491-500. DOI=http://dx.doi.org/10.1145/566654.566607.
10. Jonathan Tompson, Murphy Stein, Yann Lecun, and Ken Perlin. 2014. Real-Time Continuous Pose Recovery of Human Hands Using Convolutional Networks. ACM Trans. Graph. 33, 5, Article 169 (September 2014), 10 pages. DOI: https://doi.org/10.1145/2629500.
11. H. Kadu and C. C. J. Kuo, "Automatic Human Mocap Data Classification," in IEEE Transactions on Multimedia, vol. 16, no. 8, pp. 2191-2202, Dec. 2014.  
    doi: 10.1109/TMM.2014.2360793.
12. Hong-ze Li, Sen Guo, Chun-jie Li, Jing-qi Sun. A hybrid annual power load forecasting model based on generalized regression neural network with fruit fly optimization algorithm, Knowledge-Based Systems, Volume 37, 2013, Pages 378-387, ISSN 0950-7051, http://dx.doi.org/10.1016/j.knosys.2012.08.015.
13. Katherine Pullen and Christoph Bregler. 2002. Motion capture assisted animation: texturing and synthesis. In Proceedings of the 29th annual conference on Computer graphics and interactive techniques (SIGGRAPH '02). ACM, New York, NY, USA, 501-508. DOI=http://dx.doi.org/10.1145/566570.566608.
14. Katsu Yamane, Yuka Ariki, and Jessica Hodgins. 2010. Animating non-humanoid characters with human motion data. In Proceedings of the 2010 ACM SIGGRAPH/Eurographics Symposium on Computer Animation (SCA '10). Eurographics Association, Aire-la-Ville, Switzerland, Switzerland, 169-178.
15. L. M. Tanco and A. Hilton. 2000. Realistic synthesis of novel human movements from a database of motion capture examples. In Proceedings of the Workshop on Human Motion (HUMO'00) (HUMO '00). IEEE Computer Society, Washington, DC, USA, 137-.
16. Luo P., Kipp M., Neff M. (2009) Augmenting Gesture Animation with Motion Capture Data to Provide Full-Body Engagement. In: Ruttkay Z., Kipp M., Nijholt A., Vilhjálmsson H.H. (eds) Intelligent Virtual Agents. IVA 2009. Lecture Notes in Computer Science, vol 5773. Springer, Berlin, Heidelberg.
17. Meinard Müller, Tido Röder, and Michael Clausen. 2005. Efficient content-based retrieval of motion capture data. In ACM SIGGRAPH 2005 Papers (SIGGRAPH '05), Markus Gross (Ed.). ACM, New York, NY, USA, 677-685. DOI: https://doi.org/10.1145/1186822.1073247.
18. Multon, F., Kulpa, R., Hoyet, L. and Komura, T. (2009), Interactive animation of virtual humans based on motion capture data. Comp. Anim. Virtual Worlds, 20: 491–500. doi:10.1002/cav.281.
19. Nitish Srivastava, Geoffrey Hinton, Alex Krizhevsky, Ilya Sutskever, and Ruslan Salakhutdinov. 2014. Dropout: a simple way to prevent neural networks from overfitting. J. Mach. Learn. Res. 15, 1 (January 2014), 1929-1958.
20. P. Glardon, R. Boulic and D. Thalmann, "PCA-based walking engine using motion capture data," Proceedings Computer Graphics International, 2004., Crete, 2004, pp. 292-298. doi: 10.1109/CGI.2004.1309224.
21. S. Ferrari and R. F. Stengel, "Smooth function approximation using neural networks," in IEEE Transactions on Neural Networks, vol. 16, no. 1, pp. 24-38, Jan. 2005. doi: 10.1109/TNN.2004.836233.
22. Simon Bouvier-Zappa, Victor Ostromoukhov, and Pierre Poulin. 2007. Motion cues for illustration of skeletal motion capture data. In Proceedings of the 5th international symposium on Non-photorealistic animation and rendering (NPAR '07). ACM, New York, NY, USA, 133-140. DOI: https://doi.org/10.1145/1274871.1274891.
23. She, Ying Ying (2006) Real-time animation of walking and running using inverse kinematics. Masters thesis, Concordia University.
24. So, C. K. F. and Baciu, G. (2005), Entropy-based motion extraction for motion capture animation. Comp. Anim. Virtual Worlds, 16: 225–235. doi:10.1002/cav.107.
25. Victor Brian Zordan, Anna Majkowska, Bill Chiu, and Matthew Fast. 2005. Dynamic response for motion capture animation. In ACM SIGGRAPH 2005 Papers (SIGGRAPH '05), Markus Gross (Ed.). ACM, New York, NY, USA, 697-701. DOI: https://doi.org/10.1145/1186822.1073249.
26. Xiaolin Wei, Jianyuan Min, and Jinxiang Chai. 2011. Physically valid statistical models for human motion generation. ACM Trans. Graph. 30, 3, Article 19 (May 2011), 10 pages. DOI=http://dx.doi.org/10.1145/1966394.1966398.
27. Xue Bin Peng, Glen Berseth, and Michiel van de Panne. 2016. Terrain-adaptive locomotion skills using deep reinforcement learning. ACM Trans. Graph. 35, 4, Article 81 (July 2016), 12 pages. DOI: https://doi.org/10.1145/2897824.2925881.
28. Yao-Yang Tsai, Wen-Chieh Lin, Kuangyou B. Cheng, Jehee Lee, and Tong-Yee Lee. 2010. Real-Time Physics-Based 3D Biped Character Animation Using an Inverted Pendulum Model. IEEE Transactions on Visualization and Computer Graphics 16, 2 (March 2010), 325-337. DOI=http://dx.doi.org/10.1109/TVCG.2009.76.
29. Zarita Zainuddin and Ong Pauline. 2007. Function approximation using artificial neural networks. In Proceedings of the 12th WSEAS International Conference on Applied Mathematics (MATH'07), Metin Demiralp, Constantin Udriste, Gabriella Bognar, Ritu Soni, and Hamed Nassar (Eds.). World Scientific and Engineering Academy and Society (WSEAS), Stevens Point, Wisconsin, USA, 140-145.
30. Zhang, Qiang et al. “Keyframe Extraction from Human Motion Capture Data Based on a Multiple Population Genetic Algorithm.” Symmetry 6 (2014): 926-937.