Active Game Characters

Beyond Ragdoll Puppets

Ben Kenwright

Abstract—We want to go beyond "passive rag-doll like" simulation characters towards more "active" intelligent self-driven solutions. The "puppet on strings" approach lacks dynamic interactive properties for engaging realistic and immersive virtual environments. This paper focuses on "Self-Driven character" (e.g., procedural physics-based techniques) that balance and react in a life-like manner using physical properties (e.g., ground contacts, mass, and strength).

Index Terms—procedural, ragdoll, puppet, stepping, interactive, balancing, character, animation, physics-based, responsive, adaptive, dynamic, 3D, video-games, inverted-pendulum, ankle-torque, controllable, autonomous, intelligent

1 Introduction

The days of repetitive pre-recorded key-framed animation solutions are coming to an end. Research across multiple fields, such as biomechanics, robotics, and graphics, are now developing more intelligent self-driven systems that use physical principles to mimic human movements in a life-like way, to produce a new generation of immersive engaging and interactive character solutions.

For example, a crucial movement that is indispensable in multiple fields, such as graphics and robotics, is simulating balance recovery in a life-like and realistic way. Nevertheless, creating interactive virtual characters that react to random unforeseen disturbances and are able to recover from them (i.e., regain their balance) in a human-like way that mimics the real-world is challenging and interesting [20], [8], [10], [21], [1].

1.1 Challenges

So why is it so to reproduce life-like human movements in real-time 'and' without key-frame data? Why has it eluded us for so long? We give the main reasons here:

Realism is particularly difficult, as a particular character model gives rise to a large set of possible motions with different styles. Even if robust and stabilizing control laws can be found, it is challenging to construct those that reproduce the intricate and agile movements we observe in nature.

Then there is model complexity, since a character can have an extremely high number of degrees of freedom, making the search for the appropriate control parameters hard (e.g., adult human body has over 200 hundred bones). Although continuous numerical optimizations can cope with large search spaces, the *stringent demands of interactive applications* make it clear that optimization cannot solely be performed at the time control is needed.

The discontinuous non-linear character work-space (e.g., joint limits and contacts) restricts movement within a certain region of three-dimensional space; these constraints are difficult to maintain in real-time simulation systems, such as games. Furthermore, frequent ground contacts create a highly discontinuous search space rendering most continuous controller synthesis methods ineffective at planning over longer time horizons.

Dynamically simulated characters are difficult to control because they have no direct control over their global position and orientation (i.e., underactuation). Even staying upright is a challenge for large disturbances. In order to succeed, a control law must plan ahead to determine actions that can stabilize the body [13].

2 Related Work

How have these challenging problems of generating life-like interactive characters been solved before? Which methods have made us 'sit-up' and take notice and why? This is what we aim to address in this section.

To begin with, there are, the manually designed physics-based biped balance controllers [23], [18], which can be optimized for robust behaviors [21], [1], or combined with other techniques (e.g., motion capture data) to produce hybrid solutions with life-like dynamic responses [4]. While controller-based approaches are often intuitive and computationally fast and robust, they can be cumbersome to tune (i.e., the different parameters) and produce only simple motions (e.g., balanced standing and walking). Then again, solutions to these problems have been proposed, such as an automatic search-based algorithms to tune controller parameters automatically [20] based on velocity tracking of motion capture data.

Data-driven solutions are able to adapt character poses so they transition seamlessly [15], mix animation sequences [22] or modify sequences so they account for changing environments and disturbances (e.g., pushes) [19]. However, data-drive methods cannot generate unique motions, and highly depend on the input motion capture data.

This paper adopts a 'non data-driven' technique with a controller-based solution, that is a procedural physics-based controller approach. Where the physics-based model ensures the movement is physically plausible, the controller gives the model a goal (e.g., balanced stepping, walking, steering), and the procedural aspect provides intermediate transition solutions, such as behavioral aspects that include how the character is walking, standing, and looking around.

It is interesting to note, that if we taking a look at biomechanical research, in the area of balance, there is a reaction time for humans responding loss of balance [12], [11], [14].

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Going beyond basic stepping for balance recovery, it should be mentioned, that there are other methods of re-gaining balance, that include, grasping, stretching, and squatting strategies demonstrated in other work [2], [16], [3]. However, this paper demonstrates exploits stepping and ankle torque as a means of balance recover and control [9], [7].

This paper addresses the challenge of generating automatic key-frameless self-driven biped animations that are able to fluidly synthesize realistic three-dimensional human movement while handling arbitrary and unexpected disturbances during standing and walking. We propose the use of a low-dimensional model for generating fundamental balanced motions that are interactive and dynamic, inspired by Kenwright [6], [8] for combining physics-based techniques with a procedural self-driven model to produce autonomous real-time agents that are interactive and responsive.

3 Fractals, Physics, Biomechanics, and More

These are very exciting times for computer graphics animation. A number of diverse and original techniques are becoming plausible and practical with computers increasing in speed. For example, virtual humans solutions are mixing robotics based methods with biomechanically inspired techniques to produce more life-like physically correct and interactive characters that break the mold. The days of hard-coded, inflexible, data-driven solutions are making way for procedural self-driven smart solutions [6], [5], [17], [8].

4 The Key to Life is Balance

Controlled life-like dynamic balance is absolutely crucial. What exactly do we mean? Well it is relatively easy to create “statically” balanced movements. We can keep the overall body centre of mass above the support feet region. Timidly shifting the body mass between the left and right foot during foot transitions. However, this produces, life-less robotic-like scared looking movements, while a human, in reality, relishes its dynamic instability, constantly losing and recovering balance in an effortless life-like way. Emulating this balanced movement without key-framed data while remaining in ‘control’ is ambitious and difficult.

4.1 Stepping in holes

In the real world, the terrain is very rarely constantly flat and level. In practicality, when we step we are constrained to where we can place our feet. We need to avoid obstacles, such as holes, while remaining balanced and in control. Furthermore, navigating the terrain at a controlled speed in a particular style that mimics a human (e.g., happy or sad), needs to be included in the final solution before it can be a viable practical alternative for replacing a data-driven key-framed system.

5 Summary

Multiple factors, such as computational speed, naturalness, realism, and robustness all contribute towards what makes an animation system a viable solution. Creating an animation system that tackles each of these challenges is difficult and important. In practice, as addressed in this paper, the challenges can be subdivided into individual problems (e.g., balanced stepping, arm movement, and behavioral random motions) that are solved separately. This makes a modular solution that gives the end user the ability to swap and change different components and create a system that meets their particular demands.

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References

[1] Stelian Coros, Philippe Beaudoin, and Michiel van de Panne. Robust task-based control policies for physics-based characters. In *ACM SIGGRAPH Asia 2009 papers*, SIGGRAPH Asia ’09, pages 170:1–170:9, New York, NY, USA, 2009. ACM. 1

[2] Alexander CH Geurts, Mirjam de Haart, Ilse JW van Nes, Jaak Duysens, et al. A review of standing balance recovery from stroke. *Gait & posture*, 22(3):267–281, 2005. 2

[3] At L Hof. The equations of motion for a standing human reveal three mechanisms for balance. *Journal of biomechanics*, 40(2):451–457, 2007. 2

[4] Sumit Jain, Yuting Ye, and C. Karen Liu. Optimization-based interactive motion synthesis. *ACM Trans. Graph.*, 28(1):10:1–10:12, February 2009. 1

[5] S. Kajita, F. Kanehiro, K. Kaneko, K. Yokoi, and H. Hirukawa. The 3d linear inverted pendulum mode: a simple modeling for a biped walking pattern generation. In *Intelligent Robots and Systems, 2001. Proceedings. 2001 IEEE/RSJ International Conference on*, volume 1, pages 239 –246 vol.1, 2001. 2

[6] Ben Kenwright. Generating responsive life-like biped characters. *The Third Workshop on Procedural Content Generation in Games (PCG 2012)*, pages 1–8, may 2012. 2

[7] Ben Kenwright. Responsive biped character stepping: When push comes to shove. In *Proceedings of the 2012 International Conference on Cyberworlds*, volume 2012, pages 151–156, 2012. 2

[8] Ben Kenwright, Richard Davison, and Graham Morgan. Dynamic balancing and walking for real-time 3d characters. In *Proceedings of the 4th international conference on Motion in Games*, MIG’11, pages 63–73, Berlin, Heidelberg, 2011. Springer-Verlag. 1, 2

[9] Ben Kenwright, Richard Davison, and Graham Morgan. Dynamic balancing and walking for real-time 3d characters. In *Proceedings of the 2011 Motion in Games Conference*, volume 2011, pages 63–73. Springer Berlin/Heidelberg, 2011. 2

[10] Adriano Macchietto, Victor Zordan, and Christian R. Shelton. Momentum control for balance. In *ACM SIGGRAPH 2009 papers*, SIGGRAPH ’09, pages 80:1–80:8, New York, NY, USA, 2009. ACM. 1

[11] Lida Mademli, Adamantios Arampatzis, and Kiros Karamanidis. Dynamic stability control in forward falls: postural corrections after muscle fatigue in young and older adults. *European journal of applied physiology*, 103(3):295–306, 2008. 1

[12] RC Miall, DJ Weir, DM Wolpert, and JF Stein. Is the cerebellum a smith predictor? *Journal of motor behavior*, 25(3):203–216, 1993. 1

[13] Uldarico Muico, Yongjoon Lee, Jovan Popović, and Zoran Popović. Contact-aware nonlinear control of dynamic characters. In *ACM SIGGRAPH 2009 papers*, SIGGRAPH ’09, pages 81:1–81:9, New York, NY, USA, 2009. ACM. 1

[14] Richard R Neptune, Felix E Zajac, and Steven A Kautz. Muscle mechanical work requirements during normal walking: the energetic cost of raising the body’s center-of-mass is significant. *Journal of biomechanics*, 37(6):817–825, 2004. 1

[15] Nancy S Pollard and Victor Brian Zordan. Physically based grasping control from example. In *Proceedings of the 2005 ACM SIGGRAPH/Eurographics symposium on Computer animation*, pages 311–318. ACM, 2005. 1

[16] Xingda Qu and Maury A Nussbaum. Evaluation of the roles of passive and active control of balance using a balance control model. *Journal of biomechanics*, 42(12):1850–1855, 2009. 2

[17] MA Rongfei. Biomechanics-based responsive balance recovery animation. *Journal of Computational Information Systems*, 7(6):2087–2095, 2011. 2

[18] Takaaki Shiratori, Brooke Coley, Rakié Cham, and Jessica K Hodgins. Simulating balance recovery responses to trips based on biomechanical principles. In *Proceedings of the 2009 ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, pages 37–46. ACM, 2009. 1

[19] Kwang Won Sok, Manmyung Kim, and Jehee Lee. Simulating biped behaviors from human motion data. In *ACM SIGGRAPH 2007 papers*, SIGGRAPH ’07, New York, NY, USA, 2007. ACM. 1

[20] Yao-Yang Tsai, Wen-Chieh Lin, Kuangyou B. Cheng, Jehee Lee, and Tong-Yee Lee. Real-time physics-based 3d biped character animation using an inverted pendulum model. In *IEEE Transactions on Visualization and Computer Graphics*, volume 16:2, pages 325–337, 2010. 1

[21] Jack M. Wang, David J. Fleet, and Aaron Hertzmann. Optimizing walking controllers. In *ACM SIGGRAPH Asia 2009 papers*, SIGGRAPH Asia '09, pages 168:1–168:8, New York, NY, USA, 2009. ACM. 1

[22] Yuting Ye and C Karen Liu. Synthesis of responsive motion using a dynamic model. In *Computer Graphics Forum*, volume 29, pages 555–562. Wiley Online Library, 2010. 1

[23] KangKang Yin, Kevin Loken, and Michiel van de Panne. Simbicon: simple biped locomotion control. In *ACM SIGGRAPH 2007 papers*, SIGGRAPH '07, New York, NY, USA, 2007. ACM. 1