Master 2 internship

Walking on loose grounds

Exploring robust locomotion control on dynamically evolving grounds

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Motivations and context

The design of motion controllers for physically-based virtual creatures is a key task for many applications. They can be used to enhance the realism of 3D films or to create plausible reactive characters for video-games. In a more scientific basis, controlled characters can be used for computing visual simulations from priors. More specifically, the present work is motivated by a collaboration between our Computer Graphics group and a team of Prehistorians studying the behaviour of the early humans who lived in the Tautavel valley (south of France) 350 000 years ago. This collaboration raises many interesting questions such as: Could we infer locomotion styles for these early humans from those of modern humans and the well-studied differences of morphology? How did the early humans interact with the natural environment surrounding them (including rocks, grass, sliding gravels, mud, rivers to be crossed)? The long term goal being to provide an immersive simulation tool where prehistorians would get visual feedback from their expressed knowledge and hypotheses on early-human behaviour, such as being able to follow a prehistoric man wandering about in a typical day.

In practice, setting up locomotion controllers is very challenging. For many years, the control module computing joint forces over time to have a creature walk or run was crafted by hand [1], and had to be carefully retuned each time the character or its environment was edited - such as transferring motion skills from a male to a female character or to a child [2]. More robust motion-control approaches were then designed [3] and controllers ended up being learned using deep reinforcement learning algorithms requiring many hours of off-line training [4], possibly based on proximity to reference human motions [5]. So far, these methods have been studied for rigid, articulated character walking or running on a rigid ground (although possibly with holes and walls [4]). Indeed, deep-learning based approaches require masses of data that are not readily available for non-rigid grounds. Therefore, despite of long-lasting interest for deformable, natural environments [5, 6], adapted locomotion strategies were not studied yet, with the exception of a character walking in water [7], with interesting findings such as a raising feet strategy to save energy for low water levels. But this method still relied manual tuning for the controller and on the hypothesis of a flat, rigid ground beneath the water.

Objectives

The goal of this project is to advance towards the synthesis of robust, dynamically adaptive motion controllers for locomotion on loose grounds. More specifically, the open question we would like to address is: Could a virtual creature learn, improve and adapt on the fly to a spatially varying natural environment, as a child would do? This raises two issues: how to efficiently simulate character interaction with loose grounds such as mud, gravels, sand or snow? And how to learn locomotion control in this context, where too few examples pre-exist?

Methodology

Given the difficulty of the task, our strategy to tackle this project will be to take it from a layered-models angle: The idea is to take benefits of prior knowledge, possibly coming from kinematic methods [9] and start from a very simple, coarse representation for the animated creature – such as a physically-based animated bounding box [10], or even a deformable wheel model inspired by [11]. The designed self-adaptive controller for the coarse creature would then be coupled with either a kinematic or dynamic controller for the more detailed versions with arms and legs, enabling to add details to the resulting simulation in a coarse to fine manner.

Local, layered models combining geometric constraints with minimal physically-based layers, are also to be developed for the environment the virtual human will be traversing, including rocky slopes, gravels, sand, mud, water, or vegetation. Two approximations will be studied, one able to interact with the coarse character model and the second one with the more detailed character.

As a last experiment, robustness of the resulting adaptive locomotion controller to continuous changes in the nature of the character will be studied – from the strength of muscles progressively vanishing over time, to a creature progressively evolving in terms of morphology, such as a standard modern human morphing into a prehistoric man.

Research lab

This internship will take place in the Geometry & Visual Computing (GeoViC) team of LIX, in the Ecole Polytechnique campus (Palaiseau): Alan Turing building, 1 rue Honoré d'Estienne d'Orves, 91128 Palaiseau.

Prerequisit

Having followed one or several Computer Graphics or Computer Animation courses. Being knowledgeable in Machine Learning, with if possible notions of Bayesian learning and reinforcement learning. Programming experience in C++ or C# and knowledge of OpenGL and/or Unity appreciated.

References

[1] Animating human athletics. JK Hodgins, WL Wooten, DC Brogan, JF O'Brien. SIGGRAPH 1995

[2] Adapting simulated behaviors for new characters. JK Hodgins, NS Pollard. SIGGRAPH 1997

[3] Simbicon: Simple biped locomotion control. KK Yin, K Loken, M Van de Panne. ACM Transactions on Graphics (TOG) ,26 (3), 105, Proc. ACM SIGGRAPH 2007.

[4] Terrain-adaptive locomotion skills using deep reinforcement learning. XB Peng, G Berseth, M Van de Panne ACM Transactions on Graphics (TOG), 35 (4), 81, Proc. ACM SIGGRAPH, 2016.

[5] Deep-mimic: Example-guided deep reinforcement learning of physics-based character skills. XB Peng, P Abbeel, S Levine, M van de Panne. ACM Transactions on Graphics (TOG), 37 (4), 143, Proc. ACM SIGGRAPH, 2018.

[6] Animating sand, mud, and snow. RW Sumner, JF O'Brien, JK Hodgins, Computer Graphics Forum 18 (1), 17-26, 1999.

[7] Authoring landscapes by combining ecosystem and terrain erosion simulation. G Cordonnier, E Galin, J Gain, B Benes, E Guérin, A Peytavie, MP Cani. ACM Transactions on Graphics (TOG) 36 (4), 134, 2017.
[8] Real-time gait control for partially immersed bipeds. Samuel Carensac, Nicolas Pronost, Saida Bouakaz. Motion in Games, pp. 177-182, 2015.
[9] Automating gait generation. HC Sun, DN Metaxas, SIGGRAPH 2001.
[10] Physics-driven Multi Dimensional Keyframe Animation for Artist-directable Interactive Character. Hironori Mitake, Kazuyuki Asano, Takafumi Aoki, Salvati Marc, Markoto Sato, Shoichi Hasegawa. Computer Graphics Forum, 28 (2), Proc. Eurographics, 2009.
[11] The yoyo-man. JP Laumond, M Benallegue, J Carpentier, A Berthoz. The International Journal of Robotics Research 36 (13-14), 1508-1520, 2017.