Interactive Design of Stylized Walking Gaits for Robotic Characters

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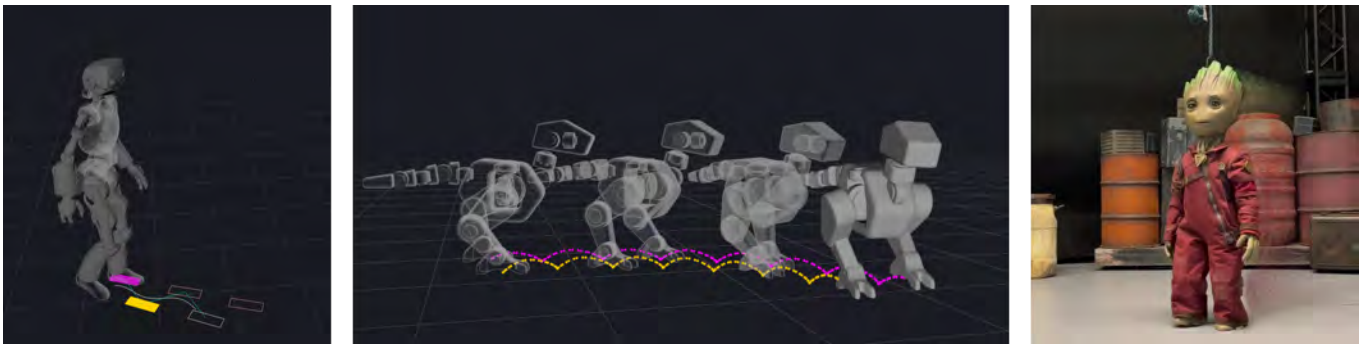

Fig. 1. **Stylized gaits designed with our interactive procedural animation technique.** An adult-sized humanoid robot walks with a casual style in sim (left). Controller reference trajectories for planned Center of Mass (white) and Center of Pressure (teal) are rendered on the ground plane along with anticipated footholds. A small-scale, dino-inspired character walks and turns in sim (center). The physical Groot robot walks along a user-defined path (right).

Procedural animation has seen widespread use in the design of expressive walking gaits for virtual characters. While similar tools could breathe life into robotic characters, existing techniques are largely unaware of the kinematic and dynamic constraints imposed by physical robots. In this paper, we propose a system for the artist-directed authoring of stylized bipedal walking gaits, tailored for execution on robotic characters. The artist interfaces with an interactive editing tool that generates the desired character motion in real-time, either on the physical or simulated robot, using a model-based control stack. Each walking style is encoded as a set of sample parameters which are translated into whole-body reference trajectories using the proposed procedural animation technique. In order to generalize the stylized gait over a continuous range of input velocities, we employ a phase-space blending strategy that interpolates a set of example walk cycles authored by the animator while preserving contact constraints. To demonstrate the utility of our approach, we animate gaits for a custom, free-walking robotic character, and show, with two additional in-simulation examples, how our procedural animation technique generalizes to bipeds with different degrees of freedom, proportions, and mass distributions.

CCS Concepts: • **Computing methodologies** → **Procedural animation**; **Physical simulation**.

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1 INTRODUCTION

While humanoid robotics is an evolving field, a number of groups have demonstrated stable, capable walking on a variety of hardware platforms. Despite this progress, stylized walking remains a challenging problem for physical robots. This is largely due to a lack of authoring tools that provide artists with fine-grain control of a robot's motion while respecting the inherent limitations of the physical system.

The field of physics-based character animation shares a common goal of enabling characters to perform expressive motions that obey the laws of physics. While recent imitation learning approaches have led to impressive results, the current focus is rather on skill than style, and existing techniques do not allow artists to directly author content. Moreover, physical robots are subject to actuator limitations and model complexities commonly unaddressed by these techniques. As a result, the expressivity and believability of animations that we can achieve on physical robots often lags behind associated results.

Procedural animation of robotic characters is challenging for two reasons: First, walking gaits must satisfy the kinematic and dynamic constraints inherent to whole-body locomotion. Second, walking gaits vary as a function of the character's velocity, and an authored