Dynamic Walking 2012 Abstract

Some observations on leg control for running from experimental data on ground birds.

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Introduction

Over the past several years, my research team has conducted numerous experiments on birds running over uneven terrain. These experiments have included varying terrain conditions such as 'unexpected' potholes, visible potholes, obstacles and single steps downward and upward. Across experiments, we have made a number of observations about leg control in running birds. Some aspects of leg control remain consistent across experiments. Here I provide a summary of our current observations and offer a potential explanation for some of these findings where possible, as a starting point for discussion. I hope this will serve as a basis for discussion of how we might control legged robots in ways that are similar to or different from animals.

Most experimental research on bipedal walking and running has focused on humans. Among animals, humans have a peculiar morphology and posture. Comparative study of locomotion, particularly among other bipeds, can help reveal general principles and highlight which aspects of human locomotion are species-specific.

Experimental data on how animals reject disturbances and negotiate uneven terrain remains sparse. We use a range of terrain height perturbations to investigate the relationships among swing leg dynamics, landing conditions, and stance dynamics. Our goal is to understand what factors influence leg control in running animals. Important factors likely include economy, stability, robustness, and avoidance of force and power limits, among others.

Our experimental work has focused mostly on helmeted guinea fowl as a model study animal, due to their manageable size and consistent performance of rapid locomotion in a laboratory setting. However, we also have data from several other species, including bobwhite quail (0.15kg), common pheasant (1.2 kg), wild turkeys (6kg) and ostrich (100kg). Where possible I will compare and contrast locomotor dynamics among species; however the comparative data available remain limited.

Findings

Our past work has shown that when birds encounter a terrain disturbance, they rarely fall, but do not maintain a steady-state gait throughout the disturbance. Continuing work has confirmed that maintaining a steady SLIP-like stance does not appear to be a top priority immediately following a disturbance. However, for obstacles up to 50% leg length, birds recover to a steady-state cycle within 2-3 steps following the disturbance.

Across terrain conditions, birds appear to minimize fluctuations in peak ground reaction force. In terrain with obstacles and drops up to 50% leg length, peak forces remain within 20-30% of that observed in uniform level terrain. Thus, experimental data suggests that maintaining similar peak ground reaction forces is a larger factor in leg control of running birds than maintaining similar body CoM trajectory. We suggest that this helps to minimize risk of injury. However, we are interested in exploring other possible explanations for this observation.

When birds encounter a terrain height disturbance, the swing leg trajectory remains remarkably constant, unless the swing leg is actually obstructed by contacting the substrate early. Near the end of swing, the leg moves backward (retracts) toward the substrate in preparation for stance, which results in adjustment of contact angle depending on flight time. Leg retraction velocity does not abruptly change upon encountering a disturbance; it remains relatively constant within a gait cycle. However, when birds repeatedly encounter 'rough' terrain conditions, leg retraction velocity increases. This increase in leg retraction velocity would tend to cause larger changes in contact angle with variations in terrain height, resulting in greater deviations from the steady-state gait cycle. It also increases the likelihood of missing a stance event entirely upon encountering a drop in terrain, which we do occasionally observe in experiments. However, increased leg retraction velocity might help avoid excessive peak ground reaction forces, minimizing risk of injury.

Open questions

Can we identify a single, simple leg control policy used by running birds across terrain conditions? That probably depends on how we define a 'single' policy, and how broadly we define terrain conditions. In the past, we have mostly avoided conditions in which anticipation and visual feedback were likely to be large factors. In ongoing work, we are investigating the role of vision by comparing terrains with high and low contrast obstacles and holes. Our current observations might be specific to high-speed locomotion over terrain with limited visibility. Nonetheless, it would be useful to identify a simple control policy that could be implemented in running robots, even over a relatively narrow range of conditions, especially if the policy can successfully reproduce the ability of animals to negotiate rough terrain at high speeds without falls and injury.

Keywords: animal/bird locomotion, experiments, stability

Preferred format: talk (15 or 30 minutes).