A low-cost, actuated passive dynamic walker kit for accessible research and education

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Summary

A low-cost bipedal walking robot kit with limited actuation and sensing capabilities was designed and built to achieve actively powered, passive dynamic walking locomotion over level ground. The walking system is composed of readily available parts and materials totaling less than $50 and can be assembled either from plans or pre-fabricated parts in less than a day. Indeed, the very first (and only) prototype was conceived and built in one day, and capable of walking within two more. In place of components utilized for the prototype shown and demonstrated, alternative parts and materials can be substituted and accommodated by relatively simple design changes, allowing this robot construction to be adapted to different resource availability, in some cases key to the success of research or education.

Introduction

Walking robots are fast becoming a new fixture of reality and not just a futuristic or academic curiosity. The main case in point of this is the current dominance of non-academic organizations leading the way in the development and implementation of sophisticated hardware and software for a variety of arguably very successful mobile walking platforms [1], [2]. While the most state-of-the-art robots have demonstrated advanced capabilities pushing the borders of research into daily application, their recent showcase at the DARPA Robotics Challenge has emphasized opposing and equally valid conclusions about the current state of the field: (1) walking robots are close to becoming useful in a practical sense, however, (2) there is plenty of work still left to be done to improve even the most advanced systems.

Among the many foreseeable improvements, first most including robustness, agility, and efficiency, the latter has been a favored topic among researchers in the community aiming to leverage the passive behavior of robotic systems to reduce the amount of energy required for over-ground walking. Many walking systems have been developed over the last few decades which take advantage of passive dynamics in this way to accomplish under-actuated walking [3]–[6].

Furthermore, this effort has drawn interest and inspiration from work beyond the field of robotics, in biology [7], [8], biomechanics [9], biomedical engineering [10], neural systems and rehabilitation [11], [12], and mathematics [13]. In these applications, using robotic prototypes as test platforms to evaluate biological and scientific principles has proven to be a useful strategy.

Nevertheless, this approach is limited if only at the very least by the practical problem of accessibility. Nearly every study of passive dynamic walking for any purpose has been conducted using unique, and custom built platforms, although the precise functionality of those systems only varies slightly. This produces redundancy in design effort, and inherently restricts the undertaking to institutions, laboratories, or research groups with both the material and personnel resources to initiate and execute the development of a walking robot from scratch – which may be out of reach even for minimalist designs, and especially to non-engineering related fields.

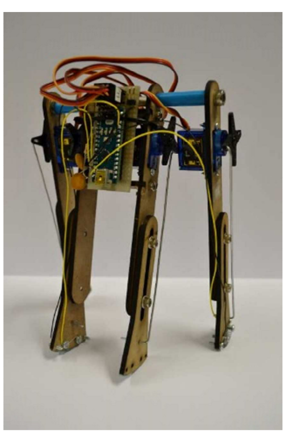
For the benefit of such underequipped groups with practical interest in relevant research, we present a highly cost-effective robotic kit capable of passive dynamic locomotion to extend the availability of technology and methods conventionally reserved for only a narrow field. Current walking robot platforms vary from very expensive, highly capable machines to more specific prototypes with limited functionality built to study or demonstrate only certain concepts. Even the more simple devices, however, are built more or less at the human scale, requiring powerful motors, and high strength materials. This presents inhibitive monetary and safety costs, which in turn prevents their widespread adoption as viable tools for any variety of scientific or educational purposes.

Methods

Our servo-actuated passive walker, dubbed *Ewok*, is built from simple, affordable components to accommodate a small scale yet conceptually functional device that can be easily built or assembled by non-technical researchers or educators. This provides the opportunity for more people to become involved in the exploration of advanced concepts involved in dynamic walking.

The primary objective in the design of an affordable passive walker was to enable generally non-technical users to fabricate or assemble a working walking device. For this reason, we followed a first principles approach in the selection of parts and materials, neglecting the paradigms established by many existing robotic prototypes in the world of research, and focusing more on parts and fabrication methods found in the hobby community. As one example, the use of aluminum and other metals was avoided for the requirement that the kit materials be easy to custom fabricate or modify, while still being robust. Instead, lightweight yet strong 3mm MDF board was chosen for the main structural components of the walker. This material is common to the hobby world as it facilitates easy cutting with a CNC laser, requiring only a 2D part file generated from any vector graphic software.

Functionally, Ewok embodies a 4-legged bipedal passive walker with one primary difference: the ability to retract and extend its legs linearly for ground clearance and push-off, respectively. This motion is enabled by 9-gram onboard servos typically employed in hobby aircraft, connected by a stiff wire push-rod to the movable lower leg (the "foot"). Two sets of legs, an outer and inner pair, are constrained to rotate freely at the top through a common axis. The final critical mechanical element of the Ewok is a pair of foot switches, one for each independent leg, each custom fabricated from compression springs. These sensors act as the only feedback to the system by activating reflexes for push-off, ground clearance, and extension without any prescribed gait pattern. Finally, the active response of the legs is delegated by an on-board Arduino Nano microcontroller.



Results and Discussion

A complete Ewok prototype was built, tested and successfully achieved stable passive dynamic walking. The prototype, like many unpowered passive dynamic walkers exhibits sensitivity to initial conditions which make it difficult at times to initiate gait, but the simple reflex-based control scheme allows recovery and convergence on a stable gait for a small range of initial conditions around a presumed optimal.

While for the present version of Ewok power is supplied through a tether from a supply unit, a future design incorporates a 9-volt battery onboard to also serve as a mass balance in place of passive hardware (washers) currently employed, which will allow for fully autonomous function.

Video

https://youtu.be/j4aEGVw3nmM

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