Towards measuring agility for legged, terrestrial locomotion

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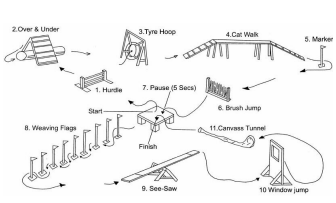
I. Disclaimer

The full work, partially described in this abstract, has been submitted for journal publication [1]. As no full disclosure is possible until the reviewers decision has been made, please accept this higher level concept without yet full specification. Normally at the time of DW the decision should be known, so that we can introduce our full benchmarking idea to the community.

II. Introduction and Motivation

Intuitively one might relate the term agility with a type of fast locomotion that incorporates a multitude of different features. We could name it fast versatility or fast maneuverability. Consequently the agility of a robot or an animal can be hard to grasp, measure and quantify. Never the less the term is often used to describe the usefulness of a legged robot in application. How should the term agility be incorporated into the description of a system, if the features that form a possible definition and its benchmark are not clear? An objective is to define it and build a corresponding benchmark may be taken from a great source of inspiration for technological systems, nature. Here agility is achieved during the animals constant fight for survival and thus appears in its most natural form. Furthermore the human strive to compare and measure themselves and their animal partners throughout various kinds of competitions leads to more clues towards finding a solution to our problem. In this abstract we will give an outlook on our work towards defining agility related to the field of multi-legged, terrestrial locomotion and its benchmarking. Creating a benchmark will enable robotics researchers and biologists to compare their research object, give new fitness functions for learning or optimization processes, identify weaknesses of their systems (mechanical or in control) as well as point towards interesting role models when starting their development process.



(a)

(b)

Fig. 1: (a) Layout of a dog-agility course with high complexity in the path and a multitude of obstacles [2], (b) Dog performing a high-jump during a dog-agility competition

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III. Agility in Wildlife, Human- and Animal-Sports

a) Agility in Wildlife: Animals, that do not live in captivity need to be self-sustainable, which means to be able to find food, reproduce, evade predators or be themselves the predator. Especially the last two points force animals to have a large variety of motion-patterns, such as crawling, sneaking, jumping, running, climbing and many others. Animals in general are not specialized in one task, although it might seem like it for some of them. The cheetah as the fastest sprinter for example ($v_{max} = 120km \cdot h^{-1}$ [3]), surely seems specialized in speed but is amongst others also capable to sneak or crawl. An elephant seems to be specialized in long distance slow motion, but when threatened it can run up to $40km \cdot h^{-1}$ and execute sharp turns [3]. An interesting aspect to look at is thus how agility can be correlated to the scale of a system or animal. If you would compare a mouse with an elephant for instance, which one is more agile? An animal in general adapts its agility to the environment and the conditions it is living in. So what is agility in animals? Is it just speed or just ability to climb or just crawl? We believe that it is a combination of all the locomotion related tasks and that they are strongly coupled to each other, especially when looking at how animals adapt their physical form to minimize energy consumption while maximizing their agility. Agility is thus not a single feature of locomotion but a group of complex motion patterns and should be related to the respective energy cost. Also agility is not something fixed to ground locomotion, but also flying, swimming and diving. As previously mentioned we will concentrate for this publication on terrestrial locomotion.

b) Agility in Animal-Sports: Looking at the field of sport that is done in cooperation of human and animal amongst others, one example of extreme agility-demonstration comes to mind: dog-agility. In this sport a series of complex movements has to be fulfilled as fast as possible and without making mistakes. Dog agility excels in the complexity of the tasks. Here the dog is to follow a pre-defined course of jumps, ramps, balancing-boards and other obstacles as fast as possible and with pre-defined accelerations and decelerations, which makes the perfect run even more difficult. The dog-trainer is allowed to give directional commands but the basic behavior is decided by the dog, of course also influenced through lengthy and intense training. Speed and fault-free fulfillment of the course are taken as the grading measures of this sport. Our observation showed that agility in animal sport is focused mainly on precision and speed.

c) Agility in Human-Sports: [4] analyzed intensively the role of agility in human sports by literature review of different sports scientists. The findings of their work are summarized below and concur widely with the observations we had from

our animal analysis.
Criteria for agility (extracted from [4]):

1) Must involve initiation of body movement, change of direction, or rapid acceleration or deceleration
2) Must involve whole-body movement
3) Involves considerable uncertainty, whether spatial or temporal
4) Open skills only (meaning skills that do not require a pre-learned stimulus to be activated; one could say: natural behavior)
5) Involves a physical and cognitive component, such as recognition of a stimulus, reaction, or execution of a physical response (the skill must be activated by recognizing its need due to outside factors, e.g. leg retraction induced by hitting an obstacle with the foot)

Agility in their opinion should incorporate the whole body with changes of direction. Reactive behaviors show the bodies general readiness to cope with uncertain situations and thus react nimbly or with agility. Preplanned behavior can make use of motion patterns one would not naturally use for the task at hand, but which can give (especially in sports) the overall best performance in this specific task. On the other hand they exclude preplanned skills like directional running from the term agility. Some of these excluded skills, like fast forward running, might in our opinion still be valid to include in the agility definition.

d) Conclusion from Wildlife, Human- and Animal-Sports: To conclude our observations of nature, there are some key aspects of locomotion that can be seen as main features to describe and thus define agility in a sufficient manner, but simple enough for further quantification:

1) Agility is not a single skill, but a complex set of motion patterns as well as the ability to rapidly switch between them.
2) ideally, reactive execution of known skills without prior planning
3) Agility varies from one species to another and thus should at least be defined differently in terrestrial, aerial and in-/underwater locomotion (in case of interest in swimming robots please refer to [5]).
4) Precision in task execution is one of the key aspects.
5) Speed of the task execution and switching if possible is another key aspect.
6) Agility is related to the scale of the system or animal and should thus be normed to attempt comparison.
7) The energy-cost to execute a task should be part of benchmarking a systems' agility.

Following this definition, we developed an easy-to-use benchmark for agility in multi-legged terrestrial robots, which can unfortunately only be disclosed fully after acceptance of the main paper. The benchmark consists of a series of values, that relate to specific agility tasks. These can easily be measured experimentally and serve as, for example, comparison values between robots but also as fitness functions for optimization processes. The benchmark was tested with data from robots available in our laboratory and verified with animal data.

IV. Questions to the DW community

1) What is the most important feature for the definition of locomotion?
2) What are the locomotion features you want to benchmark?
3) Is more benchmarking with generalized values wanted or even needed?
4) Would a generalized benchmark be used by the community or not?
5) What energy should be measured in complex robotics platforms, e.g. mechanical, electrical?
6) Which cost functions would be interesting to have for future locomotion optimization?

References

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