FIELD NOTE

The SlothBot: an ecologically inspired environmental monitoring robot

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Abstract Inspired by the low-energy lifestyle of the three-toed sloth (*Bradypus* sp.), the SlothBot is an energy-efficient, solar-powered robot designed to have a persistent presence in tree canopies. Organized around the novel robotics paradigm that surviving takes precedence over goal-driven actions, the Sloth-Bot only moves when it absolutely has to. Since May 2020, it has been taking climate measurements in the treetops of the Atlanta Botanical Garden. We envision that, in the future, teams of SlothBots can be deployed in a rainforest canopy to collect data for field ecologists.

Keywords: *Bradypus*, canopy, climate measurements, data collection, mobile robot

El SlothBot: un robot que monitorea el ambiente, inspirado por la ecología

Resumen Inspirado en el estilo de vida de baja energía del perezoso de tres dedos (*Bradypus* sp.), el Sloth-Bot es un robot que funciona a energía solar y ha sido diseñado pensando en lograr una alta eficiencia y en tener una presencia persistente en el dosel. Organizado en torno al novedoso paradigma de la robótica, según el cual sobrevivir tiene prioridad sobre las acciones impulsadas por objetivos, el SlothBot solo se mueve cuando es absolutamente necesario. Desde mayo de 2020 ha estado tomando medidas climáticas en las copas de los árboles del Jardín Botánico de Atlanta. Esperamos que en el futuro equipos de Sloth-Bots podrán ser instalados en el dosel de la selva tropical para recopilar datos para los ecólogos de campo.

Palabras clave: *Bradypus*, colecta de datos, dosel, mediciones climáticas, robot móvil

The normal way of designing robot behaviors is to define a goal, something the robot is supposed to achieve, and then maximize a reward function that encodes how well the goal is being realized (Thrun *et al.*, 2000; Choset *et al.*, 2005). Examples include how quickly a fetch-and-carry robot can deliver an item in a warehouse or how precisely a surgical robot can track a reference trajectory (LaValle, 2006). However, for robots that are to be deployed over truly long periods of time in natural environments, *e.g.*, for the purpose of monitoring environmental phenomena in order to build up ecological niche models or capture local microclimates, simply "surviving" in the environment becomes much more important than to maximize any particular reward function (Campbell *et al.*, 2010; Steinberg *et al.*,

2016). For robots, surviving could entail things such as not running into objects, never getting stranded somewhere with completely depleted batteries, or to always be in communication range with a base station. In fact, such considerations can be phrased in terms of constraints rather than rewards (Egerstedt *et al.*, 2018), which is where connections can be made between robotics and ecology, where richness of behavior oftentimes results from environmental constraints.

The SlothBot is a manifestation of this "robot ecology" idea. A collaboration between roboticists and ecologists, the SlothBot is a slow and energy-efficient, solar powered robot that is suspended on wires up in the tree canopy, measuring different climate-relevant factors (Notomista *et al.*, 2019).

FIGURE 1. The SlothBot at the Atlanta Botanical Garden.

Examples of measurements that are currently being made by the SlothBot include temperature, atmospheric pressure, humidity, solar radiation, and air quality. The benefit as compared to more traditional weather stations is that the SlothBot can spend time deep under the tree canopy, taking relevant measurements, and then use its mobility to go out into the sunshine to recharge the batteries as needed.

It is modeled on the low-energy life-style of three-toed sloths (*Bradypus* spp.), which have evolved a suite of adaptions to minimize energetic expenditure, such as anatomical specializations related to foraging digestion and locomotion, reduced activity patterns, and unique thermoregulatory behaviors (Cliffe *et al.*, 2014; Cork *et al.*, 2014; Pauli *et al.*, 2014; Dill-McFarland *et al.*, 2016). Together, these shared traits are strategies for a species to survive in the face of a precarious energy balance (Pauli *et al.*, 2016).

The SlothBot, then, does little except survive, meaning that it should not run into trees, and it should always have enough battery charge available to be able to move to a sunny spot to recharge. Since May 2020, the SlothBot has been on display among the trees in the Atlanta Botanical Garden, USA (**FIG. 1**). Currently, the SlothBot's ecological work in the Garden is limited to data collection. However, we envision a scenario where teams of SlothBots are deployed in a rainforest canopy as a highly useful and versatile companion to field ecologists by tracking pollinators and other key organisms to the overall biodiversity as well as providing the abiotic measurements needed to construct ecological niche models. If nothing else, it is certainly already serving as an inspiration to visitors to the Atlanta Botanical Garden interested in the interface of ecology and robotics.

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