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Towards Robotic Environmental Monitoring

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***Abstract*—Life on Earth is threatened by the effects of pollution and global warming. One million over the eight million species living in forests and oceans on the planet are in danger. The protection and preservation of this biodiversity can be obtained through a continuous monitoring of the ecosystems. However, nowadays environmental monitoring can be performed only by expert humans. Indeed, they only have the specific knowledge to classify plants and habitats and to assess their healthy status. Moreover, their physical intelligence allows them to walk for hours in extremely irregular terrains. Robotics could be an helpful assistant in the process of preserving natural habitats. Yet, real natural environments are still challenging scenarios for robot locomotion. Indeed, there are several issues to be tackled, e.g., unintentional contacts, uneven grounds, and long-lasting missions. This work proposes an approach to realize robotic environmental monitoring.**

I. Introduction

The average Earth surface and ocean temperature raised, especially in the last forty years [1], [2]; the sea level rose about 20cm in the last century and its growing rate is increasing [3]; and climate change is expected to continue through the current century [4], [5]. Even these few observations are an alarm bell for the conservation of the Life on Earth. Therefore, taking on time the right measures to ensure Natural protection is of paramount importance.

This can be obtained through a continuous, repeatable, and affordable monitoring of the preservation status of the natural habitats. To this end, the European Union realized the European Green Deal, which includes deeply transformative policies[1]. One of these policies aims at the restoration and preservation of ecosystems by increasing the coverage of protected biodiversity-rich land and sea areas building on the Natura 2000 Network (N2000N)[2].

Monitoring operations of this network are nowadays performed exclusively by human operators for two main reasons. First, the assessment of the healthy status of a habitat requires specific skill and knowledge. Then, human beings are the only possessing the physical ability to move in extremely irregular environments such as the natural ones.

The burden on the human workforce could be eased by robotics (Fig. 1). However, the state of the art in robotic environmental monitoring is limited and their real application is virtually null. In [6], the Authors review the main results related to this topic. Yet, the main target is underwater application such as [7], [8], while land monitoring is performed with unmanned aerial vehicles [9], [10], [11]. However, the latter solution fails when the monitoring mission requires long-lasting operations [6].

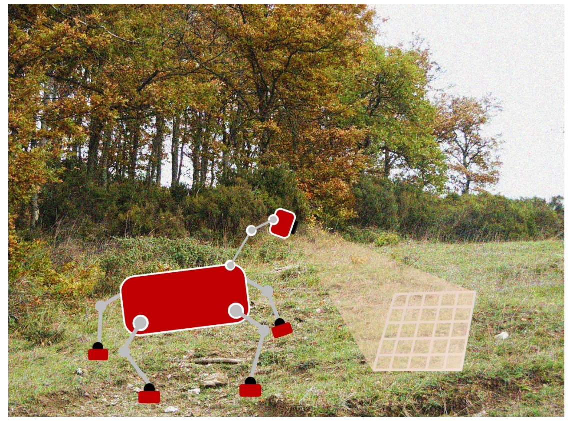

Figure 1. Robotic environmental monitoring of natural habitats.

In this work, we propose an approach to perform environmental monitoring with legged robots. The challenges to achieve such an ambitious goal are numerous and range from locomotion in unstructured environments to classification of natural habitats.The solution we propose is to empower robots with the Natural Intelligence [12] emerging by the interaction of environment, body and mind of the robot. In this context, artificial cognition addresses autonomous classification of plants species and habitats, autonomous navigation in natural environments, and efficient and effective physical environment-robot interaction. On the other hand, articulated soft-robotic mechatronics provides resilience and adaptability to the body of the quadrupedal robots.

II. Environmental Monitoring

In this section, we briefly summarize the key points of monitoring of natural habitats. The three main functions of environmental monitoring are: i) compare the current environment status with a reference status; ii) to assess the effect of actions focusing on the preservation of the natural status; iii) to assess the effects of perturbations and disturbs [13]. The EC guidelines [14] specifies that the structure and functions, and typical species that characterize a natural habitat can be measured via the assessment of its vegetation.

N2000N is composed of 9 biogeographical regions: Alpine, Boreal, Mediterranean, Atlantic, Continental, Pannonian, Black Sea, Macaronesian, and Steppic. The Habitat Directive [15] requires Members States to implement surveillance of the conservation status of habitat and species of community interest. Each country has its own decision chain.

In [16], the methodological foundations of habitats monitoring are presented. Each habitat has its own specific physiognomy, structure and characteristics, and therefore its own specific parameters indicating its conservation status.

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[2]https://ec.europa.eu/environment/nature/natura2000/index_en.htm

III. Proposed Approach

In order to deploy robots in real natural environments, we propose to confer them a *Natural Intelligence* [12], which we describe as the combination of three components: environment, mind and body.

The *environment* imposes the specification the robotic platforms should present and guides the system development thanks to the feedback obtained from field testing.

The *body* presents features such as compliance and adaptivness to grant to the robot robustness and resilience w.r.t. unexpected forceful interactions with the natural environments. This can be obtained through the adoption of soft robotic elements [17]. For example, adaptive end-effectors such as [18] enable safe interactions with unstructured environments. Furthermore, they can also improve locomotion, which is a challenging task in environments involving steep slopes, irregular grounds, and slippery surfaces such the natural ones. Analogously, soft bodies and compliant actuation enable features such shock absorption and resilience to the unavoidable contacts and falls occurring when moving in extremely harsh terrains.

The *mind* includes methodologies for planning and controlling the robot motion in natural environments. For example, autonomous navigation with legged systems is one of the most challenging task because it merges the perception of complex environments with the control problem of locomotion over highly uneven grounds. In this context, robot compliance should be considered during planning and control to maximize the system performance. Fall recovery policies should also be included to avoid mission failures. Environmental monitoring field missions are generally a time-consuming activity, which may require a full working day of an operator [19]. For this reason, energy efficiency is also a critical point to execute long-lasting robotic operations. Finally, the mind includes algorithms for the interpretation of natural habitats, with specific focus on the assessment of their conservation status.

A fourth crucial element to concretely apply robotics to environmental monitoring is *benchmarking*. This is the process of assessing the system performance by analyzing them by means of standard mythologies or references. Benchmarks are already widely diffused in many market domains, but they are not clearly and broadly established in robotics [20]. This lack of benchmarking methods, protocols, and testbeds is even more evident when referring to specific applications such as robotic environmental monitoring.

IV. Conclusions

In this work, we described what is environmental monitoring and its influence on the future of Life on Earth. Robotics could improve the ecosystem monitoring, but several issues are yet unsolved. The solution we proposed is the realization of robots with Natural Intelligence, which is the combination of body, mind and environment.

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