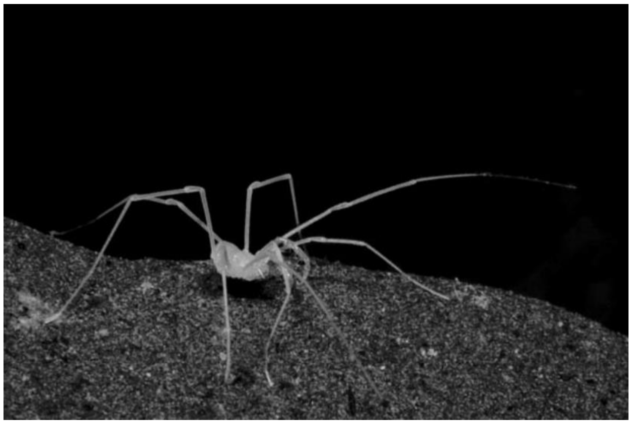
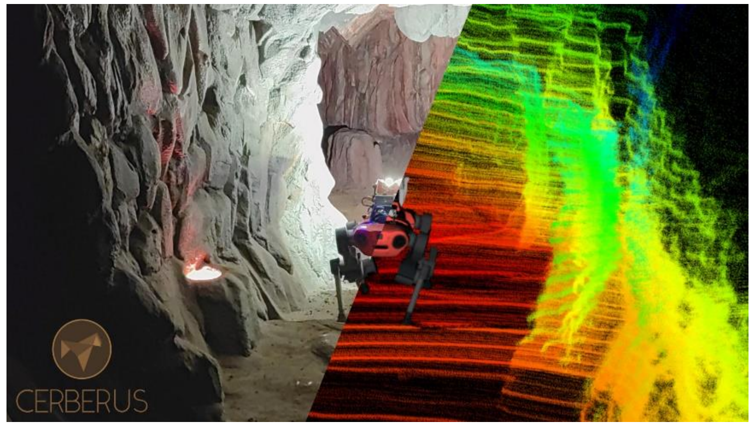
TrogloBots: Designing Deep Subterranean Robots





Abstract: Subterranean robotics and associated autonomy have been investigated with the recent DARPA Subterranean Challenge representing the most notable relevant effort. In that, Team CERBERUS won the challenge and throughout its three years employed primarily legged and flying robots all equipped with multi-modal localization and mapping fusing LiDAR, visible-light cameras, thermal vision, and inertial measurements. However, it is possible that such designs are not optimally tailored to "deep subterranean operations and environments". By Deep Subterranean Robots (DSR) we refer to systems operating autonomously – without the support of infrastructure – in underground environments that are tens and hundreds of kilometers away from the closest access point from the surface. In such environments, access to power resources are extremely limited (if any) and definitely unconventional. Thus, it is essential that such systems are extremely power efficient. Accordingly, this likely necessitates different locomotion and perception systems. Pertinent observations can be acquired by the study of "troglobites (troglobionts)", animal species strictly bound to underground habitats, such as caves. Unlike species that spend time underground only for a subset of their activities ("eutroglophiles", "subtroglophiles", "trogloxenes") troglobites have employed unique and extreme paths in evolution including the complete, or almost complete lack of eyes. Albeit the fact that in robotics we can have a set of extremely accurate active sensors (e.g., LiDAR) their continuous use is very power demanding. Likewise, their size and energetic characteristics are tailored to the sparsity of underground resources. Without biomimetic approaches not being the only possible path, in this master project the challenge is to design a true "TrogloBot", a DSR that could operate for long operations (e.g., several hours) underground with as minimalistic power consumption as possible. Example applications may include deployments in the Earth's deep subterranean voids (e.g., the 680km+ passages of the Mammoth Cave) or for exploratory scientific studies in the underground voids of other planets such as the lava tubes of Mars.

Tasks:

- Study and understand the deep underground environment and reflect on the distinct locomotion and sensing characteristics of troglobites.
- Propose conceptual designs for Deep Subterranean Robots (TrogloBots) having in mind the locomotion requirements, energy efficient and environment-appropriate sensing.
- Derive "winning" DSR/TrogloBot design and design further in CAD.
- Develop a detailed simulation model for the proposed TrogloBot.
- Prototype the proposed TrogloBot and evaluate its performance characteristics.

Literature (indicative):

[1] Tranzatto, M., Miki, T., Dharmadhikari, M., Bernreiter, L., Kulkarni, M., Mascarich, F., Andersson, O., Khattak, S., Hutter, M., Siegwart, R. and Alexis, K., 2022. CERBERUS in the DARPA Subterranean Challenge. Science Robotics, 7(66), p.eabp9742.

[2] Tranzatto, M., Dharmadhikari, M., Bernreiter, L., Camurri, M., Khattak, S., Mascarich, F., Pfreundschuh, P., Wisth, D., Zimmermann, S., Kulkarni, M. and Reijgwart, V., 2022. Team cerberus wins the darpa subterranean challenge: Technical overview and lessons learned. arXiv preprint arXiv:2207.04914.

[3] Culver, D.C. and Pipan, T., 2019. The biology of caves and other subterranean habitats. Oxford University Press.

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