Swarm robotics and archaeology: a concepts paper

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Swarm Robotics and Archaeology: A Concepts Paper

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Abstract. This concepts paper advocates for integrating swarm robotics into archaeological surveying practices. Conventional archaeological surveys, conducted on foot, often entail labour-intensive, time-consuming, and potentially hazardous tasks in vast and challenging terrains. Drawing inspiration from successful robotic missions, a swarm can assist the archaeologist in the field. The Archēbot project's primary objective centres on creating a flexible system that efficiently pinpoints areas of archaeological potential within expansive landscapes. Ultimately, the proposed hexapod robot by Teknolus emerges as a promising platform, equipped to navigate challenging terrains and withstand environmental adversities.

Keywords: archaeological survey · swarm robotics · autonomous documentation

1 Introduction

A fundamental task of archaeology is to find, identify, and record near- or above-surface past remains. Field archaeologists conduct surveys in large, heterogeneous terrains that are often difficult to traverse. Therefore, mapping features can be labour-intensive, time-consuming, and sometimes dangerous. While technologies, such as aerial imaging, offer support for how archaeologists survey, the abovementioned issues remain. Since the onset of scientific archaeology, teams have been scanning the landscapes opportunistically or in systematic transects, but almost always on foot. Significant technological progress has yet to address this most basic form of archaeological practice.

Robotic missions have become a reality, especially in exploring uncharted lands using autonomous units. One of the most well-known examples is NASA's Perseverance Rover. Yet, the current status of the Chinese Zhurong Rover is also telling: the rover was put in hibernation to protect against the Martian winter. However, researchers cannot "wake" the rover [1]-suggesting resourceful but single rover systems are too complex, and missions are prone to unexpected failures. A different approach is possible; if they

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cooperate, simple and much cheaper robotic units can still accomplish complex tasks. Swarm Robotics tackles these questions [2].

The collaboration between robotics and archaeology has immense potential. Such partnerships started in the early 70s [3]. This was followed by pioneering work in the 90s, including the Upuaut [4] and Djedi [5] Projects. Current advancements in computing technologies, especially artificial intelligence (AI), have recently changed how one can use machinery in research. In contemporary field practice, the main direction is using remotely piloted aerial systems (RPAS) or drones [e.g., 6, 7]. However, there are several issues. First, they are not best suited to wide-area exploration due to short flight times and restrictions in adverse weather conditions. Second, these systems have weight constraints, reducing operational capacities. Third, they can't interact directly with objects on the surface or partially buried in the ground, limiting their ability to identify what those objects are. Therefore, ground swarm units appear to be the ideal system to be deployed as the archaeologist's assistant.

2 Rationale and Objectives

A swarm robotics project for archaeology should aim for a scalable field system that effectively identifies areas with archaeological potential within large landscapes. This follows a two-phase plan for robotic exploration of unknown terrain. The first phase is to identify an area of interest autonomously. The second is to make sensor measurements within that area to achieve a particular task. If the terrain is enormous and contains many areas of interest, single rover systems (e.g., Perseverance Rover) are not feasible since the machine has to perform tasks consequentially.

Furthermore, an area of interest might not be that interesting after all and the machine would spend considerable time and battery power. Alternatively, swarm units can collaboratively generate a 'potential field' [8] (or an archaeological 'area of interest') and perform mapping in separate groups. Archaeology can significantly benefit from this type of flexibility and scalability. In return, archaeology can offer the perfect analogue mission; roboticists can test their autonomous designs before sending them to areas with limited intervention capacity, such as Mars.

3 An Innovative Platform

The use of swarm robotics in archaeology has implications, from conceptualizing new types of low-cost archaeology sensors for these small and "expendable" robotics platforms, as opposed to high-end research and development kits on the market, to shifts in archaeologists' labour. Using a robot in archaeology is not entirely ground-breaking, but approaching robotics research in archaeology from a landscape perspective is a game changer.

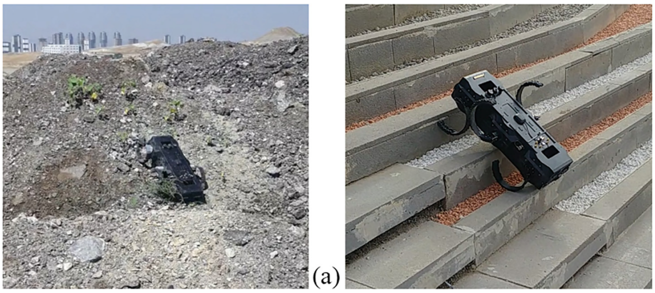
Archēbot project deploys a hexapod robot built by Teknolus [9]. The platform has its origins in RHex [10]. It is designed to navigate challenging terrains, particularly in areas where either human life is threatened, or human fatigue becomes a limiting factor.

The platform was designed with a generic framework to ensure versatility. Its software and hardware architecture are strategically tailored for seamless integration of additional sensors, actuators, and payloads. In 2022, it secured the Turkish research grant under the project 'Autonomous Advancement in Constricted Environments with Legged Robotics' (Project # 3220580). The project primarily focuses on developing semi-autonomous walking and discovery capabilities with minimal user input. In case of poor reception, the robot continues autonomous exploration of the area. Navigating through uneven terrains and finding ways through narrow passages is a key aspect.

While achieving precise mapping might pose a challenge and very high processing power, the platform maximises the utilisation of surrounding data to the best of its ability with readily available sensors. The variety of sensors collecting environmental data makes the swarm framework even more applicable. Considerable effort has been devoted to developing its networking structure, API, and user interface, providing numerous options for remote commanding. The system operates on Linux and is compatible with ROS.

The platform demonstrates substantial progress on slopes exceeding a 60% side slope (Fig. 1a). If it accidentally flips, it can operate normally, even upside-down. Apart from its standard walking capability, it offers specialised tuneable modes, including a climbing mode. With its specially designed tuneable stair mode, the platform is equipped to handle various types of stair steps, even if they are broken, missing, or uneven (Fig. 1b). The leg morphology of the platform enables progress on thick grass and bushes gravel and small to large rocks, handling an average of up to 30 cm (Fig. 2).

In addition to its capability to traverse rough terrains, the legged robot is also designed to withstand various environmental challenges. It exhibits durability against heavy impact (Fig. 3), dust and sand while being water-resistant and operable on muddy surfaces, overcoming puddles of up to 10 cm. Moreover, it demonstrates resilience to extreme temperatures and prolonged exposure to heavy sunshine. This final property is of utmost importance in the field of archaeology.



(a) (b)

Fig. 1. a) In this rubble pile, the slope averages 75–80%. Slippage may occur, resulting in occasional robot falls or flips. Nevertheless, the climbing mode is capable of gradually navigating such steep inclines. b) A sample of uneven and irregular steps.

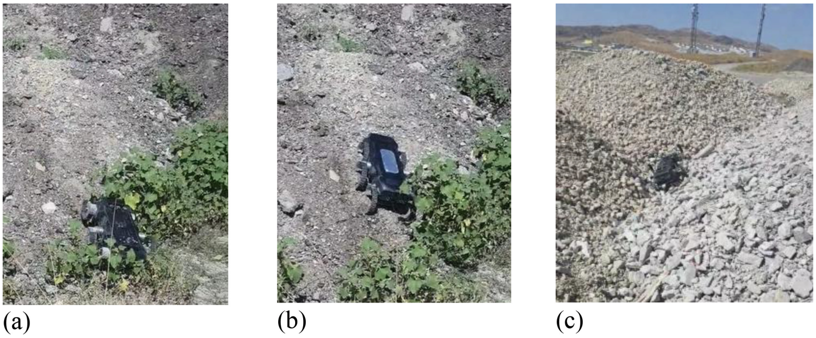


Fig. 2. The morphology of the platform enables progress on thick grass and bushes (from left to right: inside thick grass; getting out and traversing; gravel and small to large rocks).

Fig. 3. The robot faces tough, random impacts when traversing through gravel and rocks.

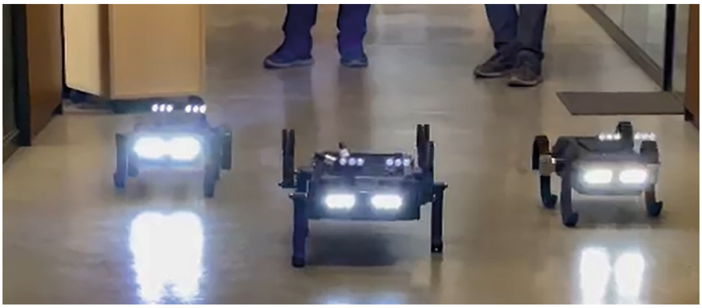


Fig. 4. The ROS compatible platform offers substantial potential for swarm applications.

The ongoing efforts of researchers in enhancing its environmental awareness speak to the platform's commitment to continuous improvement and adaptability in various settings. Its infrastructure facilitates the construction of robot swarms and enables seamless integration with a range of sophisticated sensors and systems (Fig. 4). The platform exhibits a strong potential for diverse applications, including those in demanding terrains.

4 Conclusion

Swarm robotics can alter archaeological practice and can open new sub-domains of robotics research in archaeology, such as picking relevant material (e.g., seeds, bones, etc.) with robotic "fingers" (e.g., [11]) or mapping inaccessible cave shafts and chambers (e.g., [12]). It also offers the robotics field the possibilities of cross-hybridization with “historical sciences”, a combination that can generate unexpected research paths, as seen in the late 1940s and early 1950s development of carbon-14 dating [13].

The Archēbot project can also offer a unique and fruitful combination of archaeology and robotic research. Archaeology can learn from state-of-the-art engineering practices, and robotics research can gain an unexpected disciplinary ally through which autonomous systems can be put into meaningful real-life challenges. Finally, the contributions of this fruitful collaboration hold promise to advance practices in other fields and disciplines, such as agricultural sciences [14] or planetary research [15].

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