Hillforts in Britain and Italy – Countrywide automated search for unknown sites using LiDAR data and Deep Learning

Jürgen LANDAUER, Landauer Research, Germany
Giacomo FONTANA, University College London, United Kingdom
Simon MADDISON, University College London, United Kingdom

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Introduction

The widely increasing availability and resolution of LiDAR data are revolutionising landscape archaeology allowing the identification of previously unknown archaeological features and thus aiding heritage protection strategies. This can be achieved even on a countrywide scale by using effective automation techniques. Our work aims at developing an approach to automatically detect hillfort sites cross-regionally, using Britain to train a neural network tool and Italy to test its transferability to different landscapes.

Hillforts are amongst the most evident and iconic archaeological sites in Britain. Usually associated with the Iron Age, they can date from the Neolithic to early Medieval times. The Atlas of Hillforts (Lock and Ralston 2017) provides a comprehensive and up-to-date record of these sites, over 4000 in total, and an invaluable database for further research (e.g., Maddison (2022)).

The situation in Italy is rather different. Hillfort sites have not been the object of wide-scale archaeological studies, with research that focussed instead on single sites or small local areas. The first supra-regional systematic study aimed at detecting hillforts was developed only recently in south-central Italy, in the region of ancient Samnium (Fontana 2022). Still, numerous areas of Italy remain largely unexplored, particularly in traditionally under-surveyed landscapes such as mountains and the forested regions.

The large number of hillforts known in Britain constitutes the best training dataset available to date for developing effective automation for recognising hillforts in remotely sensed data. The variety of landscapes present in Italy, on the other hand, makes this area an optimal case study for testing the transferability of this type of automation in different regions. Simultaneously, it can address the lack of systematic research on Italian hillforts providing a national-scale dataset.

Detection in Britain

Since 2020 we have been developing a neural network to detect hillforts in Britain from LiDAR data automatically. The methodology and the workflow were presented already at various conferences (e.g. Landauer and Verschoof-van der Vaart 2022) but, since then, they have been substantially improved using an extended database of sites. Despite still being a work-in-progress, the approach

has shown to be effective in a substantial part of Britain. It assigned to each land patch on a 500m grid a confidence score between 0 and 100 percent, corresponding to the likelihood that this patch contains the remains of a hillfort. An example depicting a region in northern England can be seen in figure 2. Here, six black dots indicate known hillfort locations, while orange boxes correspond to computation output patches with high confidence scores (90 percent or higher in this case). One can see that all known hillforts were found with two more boxes indicating possible unknown sites with similarly high scores.

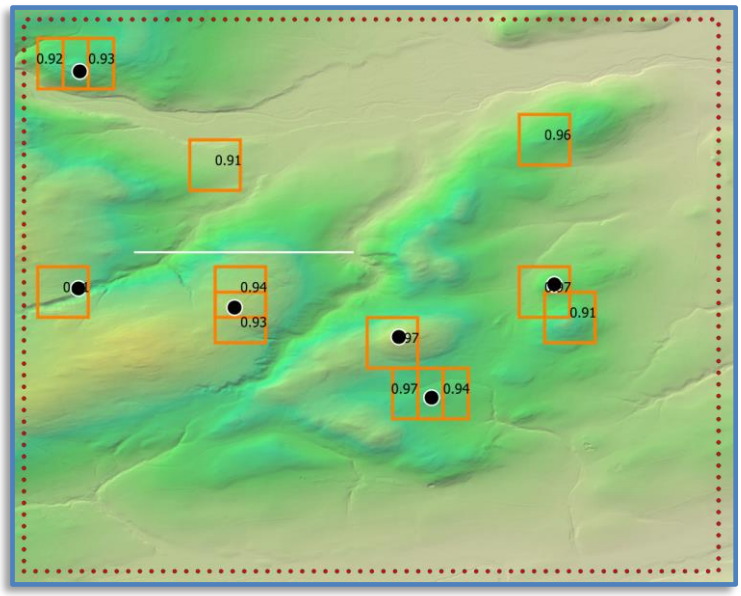

Fig. 1. Detection results in a region of northern England. Orange: detections. Black: confirmed hillfort locations. Numbers indicate confidence scores (filtered: 90 percent or more)

Transferability in Italy

The application of the tool in Italy highlighted both the potential and the limitation of transferring the neural network to different landscapes. The neural network trained on British hillforts was initially tested on selected small Italian areas where hillfort locations were known to see whether its output was - in principle - applicable to landscapes with rather different characteristics. The result of this limited test was promising, confirming the tool's ability to detect hillforts sites in diverse landscapes (fig.2). However, many locations were falsely classified as hillforts, and the majority of these turned out to be in those types of landscapes that are not present in Britain, such as the heavily terraced hilly areas of the Italian Apennines. These areas were affected by large-scale terracing works across the centuries, with the latest dated to just a few decades ago when large areas were modified for arboriculture. For this reason, the linear features characteristics of hillfort sites are often in between other similar one, the terraces, creating a stratified landscape of walled enclosures that is challenging to interpret)fig.3). Intuitively, the neural network had difficulties with terrace data as it had never "seen" this terrain type before. To address this, we decided to re-train the neural network, including many LiDAR samples with terraces (10% of the training data). This neural network training technique called "transfer learning" implies that a network trained on a different domain is modified (or re-trained) to also deal with a slightly different domain. The preliminary results obtained from this approach are promising, showcasing the flexibility of the neural network in detecting hillfort sites also in areas which would be already challenging for the human interpreter.

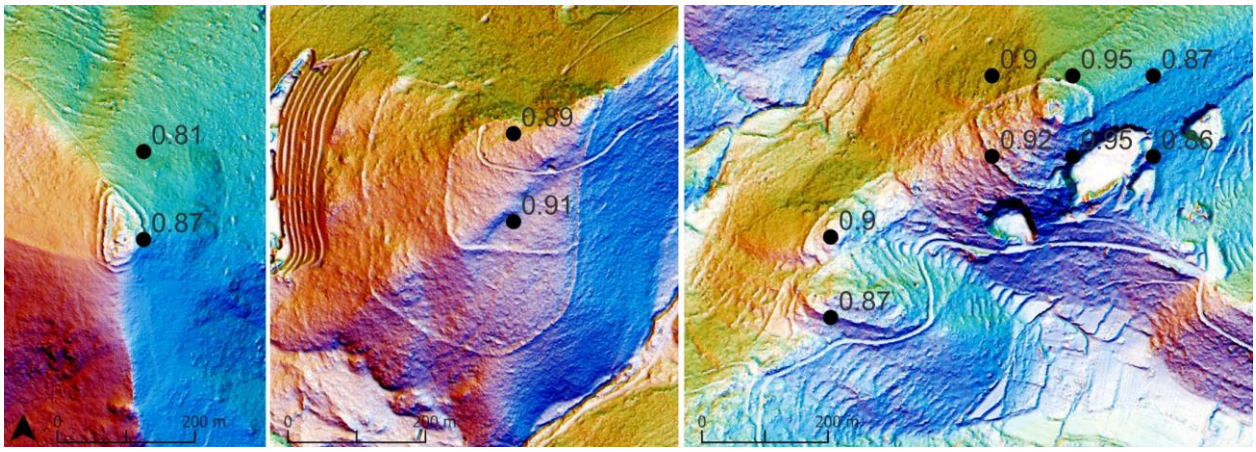

Fig. 2. Detection results for known sites in Italy with indicated the confidence scores (filtered: 90 percent or more).

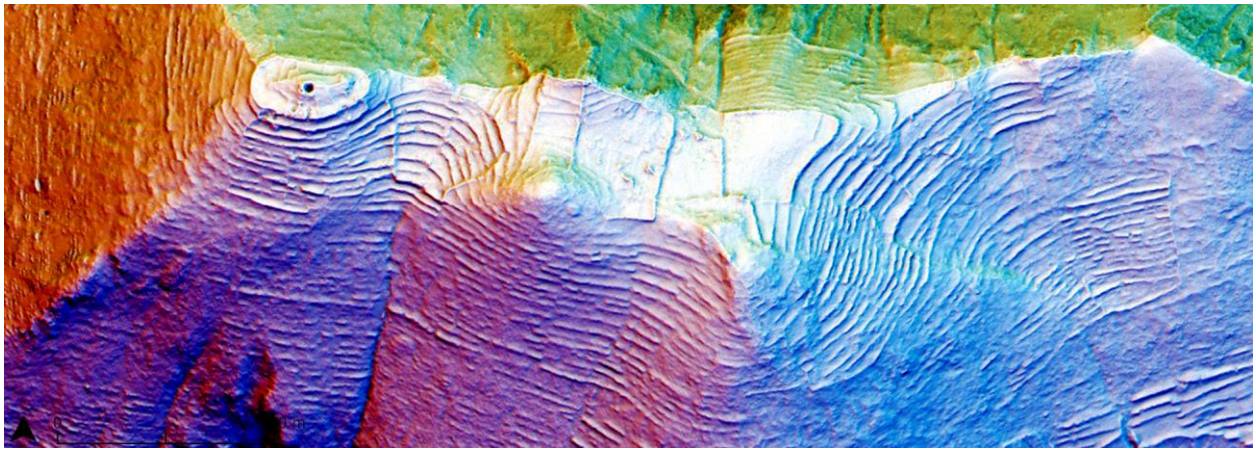

Fig. 3. Example on a hillfort located in heavily terraced landscape typical of the central Apennines.

A working agenda for developing countrywide automation

The preliminary results obtained from applying the neural network in Britain and Italy allowed us to identify some key themes to address for the development of countrywide automation for archaeology. These are:

1) The relationship between detection and landscape types. What (statistical and other) impacts have differences in topography on detection quality? For example, are highland hillforts detected more easily?

2) The detection quality in relation to hillfort types. Are hillforts of different types detected uniformly, i.e. all with the same likelihood? Or are there differences between less common sites such as promontory forts and more widespread forms?

3) The impact of regional variations. There is a significant variation in the density and nature of hillforts across Britain, e.g. between southeast Scotland and southwest England. Which is the best strategy in the selection of a training dataset? Can we develop a single neural network for the whole country, or is it necessary to run the detection on a regional basis?

4) What is the best strategy to validate the detections? Which combination of approaches between using other types of data such as available satellite imagery, field prospection or Historic Environment Records is the most effective? This is a crucial issue in the new Big Data era.

Conclusion and further work

This research contributes to automating the detection of previously unknown archaeological sites in two ways. First, we have shown that a suitable database of existing sites can be used to train a state-of-the-art deep learning system to accurately find numerous possible new sites of that type (with a high likelihood). This comes with a high degree of automation and reasonable processing times, even at a countrywide scale. Second, we showed that these results are – at least in principle – transferable to other landscape types, in this case from Britain to Italy. This works well even if the nature of the landscape is significantly different, as shown with the example of terraces in Italy, if specific transfer learning techniques are applied.

We believe that the obtained results on hillfort detection quality are also likely to be applicable to other types of archaeological features. As a long-term objective, the findings of this project (and similar automatic detection projects) could therefore serve as the basis of a future quality benchmark for the automation of archaeological feature identification from remote sensing data cross-regionally.

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Conflict of Interests Disclosure

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Author Contributions

Conceptualisation: all authors
Data curation: G. Fontana, S. Maddison,
Methodology: all authors
Resources: all authors
Software: J. Landauer
Writing – original draft: all authors
Writing – review & editing: all authors

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