Applications of Mobile Technology in Archaeology

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Archaeologists in their quest to understand the way of life during the various phases that mankind has come through, spend a lot of their time investigating any pieces of evidence they may have come across during their field work. Gathering of data concerning these ecofacts and artefacts is carried out using a wide variety of methods which continuously try to incorporate the latest advances in science and technology. Many of these cutting edge devices, however, cannot be used extensively owing to their prohibitively high costs, or difficulty in incorporating on certain terrains. A significant aspect of modern day life is mobile technology which has grown by leaps and bounds, and these advanced devices have numerous untapped potential applications in a large number of fields. This paper explores the possibility of using these devices in conjunctions with other accessible everyday technology as a low-cost, resourceful alternative to custom-made devices.

I. RAKHIGARHI, A CASE STUDY

The town of Rakhigarhi, belonging to the Hisar district in Haryana, India, has very recently been declared as the largest settlement belonging to the Harappan period in the light of newly discovered mounds redefining its area to be over 2180 hectares[1]. The Harappan, or Indus valley civilization , is one of the oldest, and longest surviving urban cultures in history. Documented sites have shown an unbroken chain of archaeological evidence starting from around 6000 B.C, to its mysterious downfall around 1800 B.C. . Over 4000 years of human history are packed into the soil in this region and yet, a large part of this culture remains to be understood. Rakhigarhi, therefore, holds out new promise in regard to offering fresh data[2].

The Harappan civilization was contemporaneous with the ancient Mesopotamian and Egyptian civilizations, and was also a trading partner, and the scant understanding we have of it makes the findings at Rakhigarhi even more important. However, the sites are in dire need of conservation. It has already been listed among the top ten endangered global heritage sites by the Global Heritage Fund. Rampant urban encroachment, farming, and vandalism pose an active threat. At one of the sites, the lone security guard hired by the ASI is at large, and even artefacts with inscriptions in an as yet undeciphered script sell for as little as Rs. 200 to foreign tourists[6]. The fenced off mounds are encroached by villagers for drying cow-dung cakes.

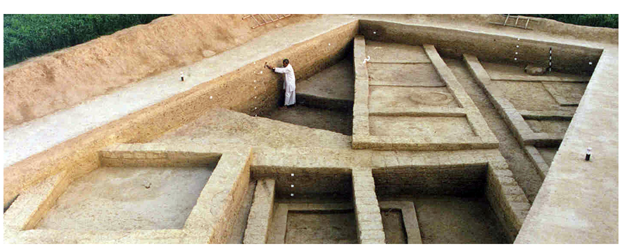

FIG. 1: Rakhigarhi monuments and streets exposed in earlier excavations that have now been *reburied*[3]

Fig 1 is proof of the complexity of constructions belonging to the ancient civilization, but it must also be noted that these excavations had been reburied. All I could find was this lone image of this site, and given the technology existing during the time of these excavations, absence of Digital terrain maps will not be surprising.

Modern technology can easily generate 3-D maps, but if the state of affairs are anything to go by, monetary resources available with the Archaeological Survey of India(ASI) are quite scant. This has been reaffirmed by top officials.

A. Use of GPS enabled mobiles to map elevation and annotate points of interest

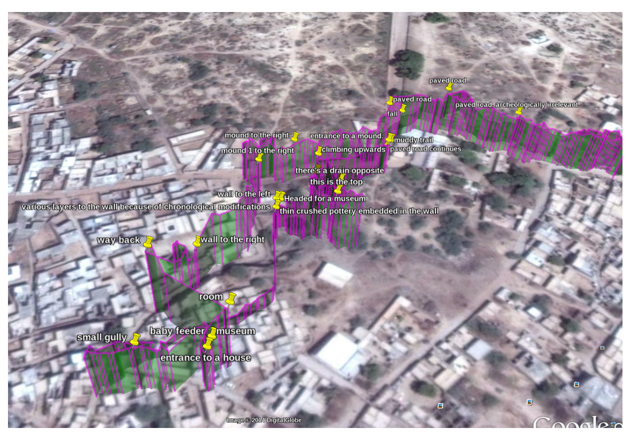

FIG. 2: Image generated by mapping GPS data from a custom Android Application onto a google earth view of a site at Rakhigarhi. The elevation has been offset by fifty metres for better visualization.

Acquiring large area maps based solely on physical evidence is impractical. A wide range of factors prevent ex-

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cavation of entire cities, and archaeologists need to rely on extrapolated data and software based reconstructions. Fig 2 is a proof of concept of the data acquisition capabilities of modern day mobile phones. A walking tour of the city of Rakhigarhi was recorded using a custom mobile application coded using the Java programming language. This is extremely simplistic in its approach, and simply logs GPS coordinates, and allows users to make notes wherein spatial information is automatically encoded. The gathered data is then converted into kml files using a Python script in order to upload and visualize the routes on Google Earth. Elevation data on google earth has extremely low resolution in most areas, and is largely useless for areas less than a kilometre square in size. GPS data from the mobile app however, contains elevation data within a 2 metre resolution, and this can be further improved by the use of more advanced handsets, or external GPS modules.

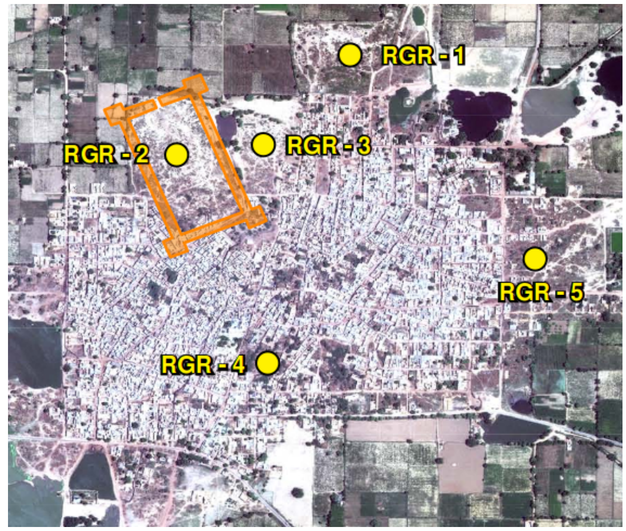

FIG. 3: Image from a publication[4] by the Global Heritage Network on Rakhigarhi, marking the positions of some of the mounds that have been identified(1997-98).

B. Interpolation of 2D routes to generate 3D terrain information

Data gathered from handsets of team members can be fed into a common map, and polygon fits of relevant elevation data(read: belonging to the archaeological phase)can be obtained in order to generate a 3D landscape of the region. With sufficient datapoints, finer features of interest such as fluvial ridges, and transportation routes can be sufficiently described. Such user generated models can be very flexible when it comes to reconstructing landscapes.

C. Extrapolation of textures for finer visualization

Keeping with the fact that excavating vast areas is too resource intensive among other reasons to be practical, I would like to put forth the potential use of extrapolating large area features such as roads and drainages based on a single section that is well preserved.

Archaeologists recover structures with varying degrees of preservation. These may range from fully intact foundations, to mere clues remnant of the existence of such structures. User friendly 3D visualization software discussed in later sections can come in very handy in making the best of what is available. Since such software allows users to construct cities from a set of textures, a well-preserved section can be input as a texture, and can be extrapolated over large landscapes wherever clues which confirm their existence can be found. This way drainage maps, and roadmaps can be digitally reconstructed in order to ascertain trade routes, and predict locations of important heritage sites where excavations can be pursued.

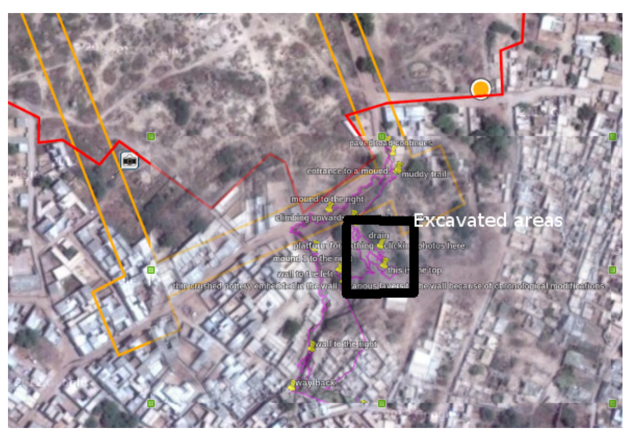

FIG. 4: Route taken during field trip, and points of interest(black bounding box) overlaid on a recent satellite map along with locations of earlier excavations at Rakhigarhi(1997-98)

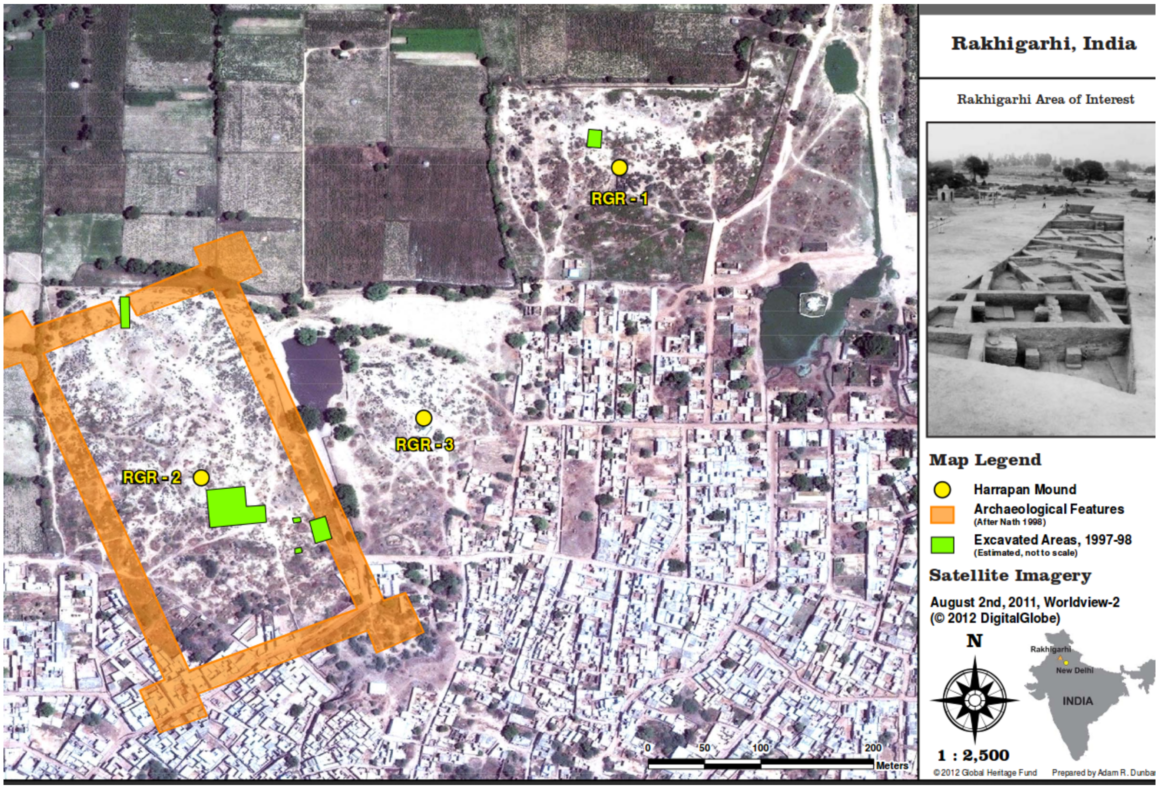

FIG. 5: Locations of areas excavated in 1997-1998 at Rakhigarhi

FIG. 6: An attempt to recreate the contours of a series of excavated houses shows the limitations of mobile GPS. An error margin of about 1 metre obfuscates the positions of the wall boundaries that I had attempted to trace. Elevation data suffers from similar precision errors, but the slope being gradual, the error margin is more acceptable. The measured coordinates being absolute, visualization of several such paths on a common platform will provide a clearer picture.

FIG. 7: An example of a user generated Minecraft village

FIG. 8: A complex map

II. COMPILING DATA INTO A UNIFIED ONLINE DIGITAL WORLD

Recreating archaeological cities in a digital space offers a deeper insight into the phase under consideration. Here, I will try to introduce the possibility of using an established genre of video games which allow players to construct their own cities and nations in a common digital space. This section will deal with the hugely successful sandbox indie game known as Minecraft. With an active user base of over 33 million, it allows players to construct entire 3D cities using texture blocks, and it has great, tested potential when it comes to building real world replicas. Given the enormous user database that can currently be handled by its servers, and considering the fact that the majority of the users are less than ten years of age, the numerous complex creations are testimonials to the ease of use, as well as scalability of this platform.

Archaeological evidence is better preserved underground rather than in an excavated and unprotected state where it may be subject to looting as well as erosion by man-made causes such as pollutants which are much harsher than mere soil . Fig 1 shows one such site which was excavated in 1997-98, and was reburied. Reburial may also be due to other problems such as land ownership issues or lack of resources for further pursuit. With the advent of digital databases however, detailed maps can be preserved in the form of 3D texture maps for perusal by the community of archaeologists as well as amateurs worldwide.

A. Minecraft map of Great Britain

Great Britain's national mapping agency, Ordnance Survey[5], put together an entire Minecraft world in order to better represent the vast amount of data they had of Great Britain. A combination of OS Terrain50, a digital terrain model which contains elevation data, and OS VectorMap district which offers a district resolution view of the nation was used to achieve this.

Software was used to analyse their data and generate the equivalent Minecraft world consisting of 22 billion blocks, and is free for download by any of its users. This rough terrain and elevation map can be edited by users in order to incorporate finer structures, and terrain.

The potential pedagogical applications of these efforts as listed on their website involve Drainage assessment, asset management, environmental impact assessment, landscape visualization, and utilities and management.

These efforts can be taken as a proof of concept for recreating landscapes from various anthropogenic phases towards a similar end.

B. Block by Block, a UN habitat initiative

UN habitat, in cooperation with the makers of Minecraft, began the Block-by-Block project to recreate real world environments in Minecraft world. This has been pursued with the object of allowing young people to create the design changes they would like to be implemented. This project supports UN habitat's *sustainable urban development network* to upgrade over 30 public spaces using resident collaboration.

This can be directly adapted for archaeological pursuits

III. IMAGE PROCESSING TOOLS FOR 3D SCANNING

With the increased processing powers that smartphones now ship with, tools which were earlier available only on desktops have now started appearing on mobile platforms. One of the important new additions is the OpenCV Image processing library which was developed at Intel, and is now widely used in industry for an array of applications.

3D scanning using a line laser (a technique similar to LiDAR, but on a much smaller scale) has become hugely popular nowadays. A vertical line laser is used to illuminate the object to be scanned, and a camera records the object from an angle. When viewed from an angle, The laser line appears deflected based on the elevation of

FIG. 9: 3D scaning using a smartphone and a line laser

each point [7]. The Image processing is used to extract the contours of the laser, and basic trigonometry can be applied to extract the height profile based on the angle of the camera, and the distance from the object being scanned. The object is then slowly rotated about its vertical axis, and height profiles are extracted over its entire surface in order to render a 3D model.

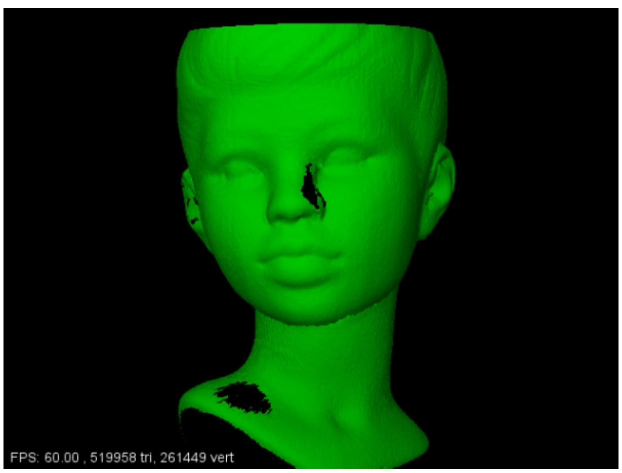

FIG. 10: The completed scan generated after processing. The unscanned areas are where the laser line was overshadowed by a large feature, and this is one of the limitations of single azimuth scanning. Airborne single azimuth LiDAR techniques also suffer from such limitations, and it can be partially resolved by using two cameras located on either side of the laser

There are several low cost 3D scanners available at affordable prices for amateur use[8–10] . Many of these sell with 3D printers too, and these can be used to transfer digital copies of artefacts such as seals and inscriptions around the world where replicas may be printed if required.

IV. APPLICATIONS OF ACCELEROMETERS AND MAGNETOMETERS

Smartphones generally come equipped with sensors allowing measurements in 9 degrees of freedom. This includes data from 3-axis magnetometers which are capable of measuring magnetic field vectors with upto $250nT$ of accuracy, 3-axis accelerometers which measure acceleration vectors, and 3-axis gyroscopes.

Accelerometers measure acceleration forces inclusive of the earth's gravitational acceleration force. This means that the value read in the downward direction by a stationary accelerometer is always around $9.8m^2/s$. This makes accelerometers an easy to use replacement for spirit levellers while carrying out excavations. They can be used to determine azimuthal angles while drilling.

The earth's field varies from as little as $22uT$ in Brazil to as much as $67uT$ in Antarctica. Therefore, mobile magnetometers can be used to estimate the magnitude as well as angle of dip at survey locations.

Some smartphones come equipped with magnetometers which have a resolution of 16-bits over a 4 gauss range. This translates to a 5 nanoTesla precision. Magnetic gradiometry requires a precision of less than 100nTesla, and thus potential applications can be seen in this field if two smartphones are attached to a contraption similar to those used for gradiometry. Gradiometry enhances ground anomalies in the magnetic field, and are useful for site investigation. It also serves as a cheaper alternative to ground penetration radar with some tradeoffs in the range of materials that can be scanned. However, noise levels from the electronics surrounding the magnetic sensor may seriously hinder the capabilities. Experiments need to be conducted in order to verify the ability of a smartphone based gradiometer to locate underground artefacts and structures.

V. CONCLUSION

It has been shown that affordable technology can be used for archaeological pursuits with appropriate software based developments. Smartphones manufacturers in the race to win consumers have developed products which pack a wide array of sensors into them despite being far less expensive than if these sensors were bought and implemented independently. In conjunction with mapping tools such Google Earth, and Streetview which combines spherical panoramic photographs and spatial data to give the impression of being in a real 3D space, powerful tools can be developed for exploration and digitizing.

[1] http://www.thehindu.com/features/friday-review/history-and-culture/rakhigarhi-the-biggest-harappan-site/article5840414.ece
[2] http://www.ancient-origins.net/news-history-archaeology/rakhigarhi-now-biggest-harappan-site-after-two-new-mounds-discovered-001500
[3] http://globalheritagefund.org/what_we_do/overview/investigations/rakhigarhi_india
[4] http://ghn.globalheritagefund.com /uploads/documents/document_1982.pdf
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