COMMUNITY MAPPING BY NON-LITERATE CITIZEN SCIENTISTS IN THE RAINFOREST

Michalis Vitos, Matthias Stevens, Jerome Lewis and Muki Haklay

Abstract

Supporting local communities to share their environmental knowledge by utilizing scientifically accepted tools and methodologies can lead to improvement in environmental governance, environmental justice and management practices. Mbendjele hunter-gatherers in the rainforests of Congo are collaborating with the ExCiteS Research Group at University College London to record their local knowledge about illegal poaching activities, which will improve the control of commercial hunters and diminish the harassment they often experience at the hands of 'eco-guards' who enforce hunting regulations. Developing and deploying a system for non-literate users introduces a range of challenges that we have tried to tackle with our Anti-Poaching data collection platform.

Keywords

Citizen Science, Mobile Sensing, Development, Conservation, Natural Resource Management, Social-Environmental Justice

1 Introduction

Sustainable natural resource management is one of the major development challenges facing humanity today. There is an urgent need for innovative solutions to enable scientifically informed, sustainable resource management of key environments such as the rainforests. The tendency to impose draconian floral and faunal management laws and practices designed by technocrats and politicians from outside the affected areas has disenfranchised local people from any say or involvement in the management of the areas their livelihoods depend upon. However, encouraging local people to share their environmental knowledge more effectively leads to improvements in environmental governance, environmental justice and management practices.

The Mbendjele are the indigenous people of northern Congo-Brazzaville. As expert hunters and gatherers of wild produce they move through huge areas of forest over the course of the year. The Mbendjele and other forest-dependent people are among the poorest citizens of Central Africa's countries and the groups most dependent on natural resources for their livelihoods, yet they are rarely consulted in decisions over the attribution, or involved in the management of, these areas. In 2005, the local logging company, *Congolaise Industrielle des Bois* (CIB), decided to seek certification by the Forest Stewardship Council (*http://www.fsc.org/*) as being environmentally and socially sustainable. Part of the requirements forced CIB to respect the rights and resources of indigenous and local forest people. A solution was developed by a consortium that introduced the Mbendjele to the use of rugged Personal Digital Assistance (PDA) devices, portable GPS (Global Positioning System) receivers, and bespoke software that allowed non-literate users to record observations using a pictorial decision tree (Hopkin, 2007; Lewis and Nelson, 2007; Lewis, 2012). In 2007 a similar initiative was set up in Cameroon (Lewis and Nkuintchua, 2012).

Nowadays, the Mbendjele are very concerned about over-hunting by commercial poachers in their traditional hunting areas. The traps such poachers leave concentrated in small areas ravage animals indiscriminately, and pose a danger to the hunter-gatherers and their children as they move throughout the forest. These poachers are dispersed in small forest camps and are typically armed with shotguns, Kalashnikovs and other rifles – posing a threat to locals, especially if they try to meddle in their activities. The poachers are known to bribe local law enforcers called 'eco-guards' and are often part of larger networks supported by local elites keen on profiting from their highly lucrative business. Hence they operate with relative impunity. Eco-guards looking for easier targets often visit Mbendjele and other local communities where they too often resort to violence and abuse. The Mbendjele experience this as unacceptable persecution for something that they see as their birthright – to live by hunting and gathering wild foods from the forest, as have their ancestors since time immemorial.

Building on their positive experience by mapping their resources to protect them from logging activities (Lewis, 2012; Lewis and Nkuintchua, 2012), some Mbendjele requested Lewis to design them a tool for recording their extensive knowledge of the whereabouts and habits of poachers. Together, they visited the offices of the Wildlife Conservation Society manager helping to organize the eco-guard patrols, to propose the idea and to discuss what issues they would like to monitor and, from the eco-guards' point of view, to identify the evidence they would need to record in order to effectively charge and arrest the poachers.

Our collaboration with the Mbendjele, as described in this article, is exemplary for the *raison d'être* of the ExCiteS group at University College London. Our mission is to co-develop information and communication technology (ICT) solutions with participating communities in order to enable them to capture their extensive environmental knowledge in ways that can be efficiently shared with outsiders and promote their control of their land and resources. In doing so, we seek to push beyond traditional citizen or community science projects (Dickinson *et al.*, 2012; Haklay, 2013), which typically target educated people in affluent areas of the world. We call this approach Extreme Citizen Science (ExCiteS), and expect it to have transformative potential to deal with major sustainability challenges by making scientifically valid datasets available to a wide range of users in accessible formats – even if they are not literate.

2 Challenges

Deploying ICT systems in the rainforest and putting devices designed for educated, literate people in the hands of unschooled, forest people presents numerous foreseeable and unforeseeable difficulties. We tried to pre-empt the most obvious of these – the low or non-existent literacy of the users of the system – in developing a suitable solution. The users have never had any formal education, and have only basic experience of technology through handheld devices that were used in the past. Illiteracy is a huge obstacle to using devices such as smartphones because virtually any standard user interface (UI) includes various textual and numerical elements. A related challenge is language: only a handful of Mbendjele speak an international language and their own language is spoken by few outsiders.

The overall technical challenge is providing the Mbendjele with a platform that allows them to report poaching- related activities in the forest and to feed this information into a central database in time for appropriate control activities to be organized successfully. We need a mobile device that can withstand the adverse conditions of the African rainforest: dust, mud, high humidity levels, and frequent rain. It also needs to be robust, such that it does not break when roughly handled for extended periods of time by people who have no experience in dealing with delicate electronic equipment. Furthermore, it should be equipped with a GPS receiver that is sensitive enough to get location fixes under dense forest canopy within a reasonable amount of time (e.g. within five minutes). Finally, it should be relatively cheap; affordable to non-governmental organizations and potentially indigenous communities themselves. In terms of software, although there are many existing frameworks and applications for mobile data collection, the nature of this project and its requirements made off-the-shelf solutions impractical.

There are also numerous practical challenges that need to be tackled. The lack of power facilities in the rainforest, especially when combined with the high power demands of smartphones or other handheld devices, poses a major challenge. Furthermore, although it is fast expanding, cellular network penetration and coverage remains limited in developing countries, especially in vast, sparsely inhabited areas (Parikh and Lazowska, 2006), which is problematic because we need data to be uploaded to, and synchronized with, a central database.

Finally, perhaps the most challenging problem is that of security; more specifically, personal safety. Given the nature of the data collection activity, the consequences of an Mbendjele member being caught in the act by poachers could be dramatic, possibly even fatal. Therefore the equipment should be discreet, easy to carry around, and, if necessary, easy to hide or discard. Moreover, the true purpose should be deniable – in part by restricting access to the data collection software.

3 Related Projects

Paper-based survey forms for collecting information in the field remain widely used across many scientific disciplines. However, advances in ICT have enabled data collection via digital forms and allow the data to be fed directly into an electronic database, making data collection more efficient, cheaper, and less error-prone when compared to traditional methods (Pundt, 2002). Before deciding to develop our own platform, we evaluated several existing platforms for mobile data collection. We found they all had limitations or restrictions which made them unsuitable for our goals.

The first mobile data collection platforms were designed for handheld computers or PDAs (Lane *et al.*, 2006). CyberTracker (*http://www.cybertracker.org/*) and EpiHandy (*http://www.epihandy.org/*) are examples of such early, PDA-based platforms. Nowadays both are outdated, primarily because they rely on expensive and equally outdated PDA devices that lack the processing power and built-in sensors of today's smartphones. The next generation of mobile data collection platforms targeted mobile phones and smartphones. EpiCollect (Aanensen *et al.*, 2009), an initiative of Imperial College London, and Open Data Kit (ODK) (*http://opendatakit.org/*), created by the University of Washington (Anokwa *et al.*, 2009; Hartung *et al.*, 2010), are examples of such modern platforms. Besides the data collection applications, both also offer online tools to design forms, visualize data (using Google Maps) and perform basic analysis. However, because EpiCollect is designed for literate scientists, it is heavily dependent upon textual interaction and does not support the use of pictorial icons and decision trees. On the other hand, ODK requires verbose and complex XForms structures to implement a decision tree consisting of pictorial icons. Moreover, due to textual information in the UI, the standard ODK Collect application would be too confusing for non-literate users.

Still, because it is open source, we decided to use ODK Collect as the basis for our first prototype platform and modify it to suit our needs.

4 Platform Prototype

Currently, our Anti-Poaching data collection platform is in an advanced prototype state. Below we discuss the different hard- and software components.

4.1 Hardware

In order to withstand the harsh rainforest conditions and not-so-gentle treatment by the users, we looked for a rugged, water-resistant smartphone. While there is an increasing number of such devices on the market, most are designed for military or industrial clients and command correspondingly high prices. Fortunately some mainstream smartphone vendors have recently introduced much cheaper rugged devices such as the Samsung Galaxy Xcover (Samsung, 2011), which we eventually selected. This Android-based smartphone has a durable body, a scratch-resistant Gorilla Glass screen (*http://corninggorillaglass.com/*), and is IP67-certified (International Electrotechnical Commission, 2012), which means it is dustproof and also waterproof (at depths of up to one metre).

We tested two possible solutions for charging the devices in the forest. The first was a combination of a roll-up solar panel and an external auxiliary battery that stores energy for later use. This solution was not expected to be sufficient for use in the rainforest because there is little direct sunlight reaching ground level due to the dense canopy. The second solution was the Hatsuden Nabe, a Japanese-produced customized cooking pan that converts thermal energy from a fire into electricity that can be used to charge electronic devices while cooking (TES NewEnergy Corporation, 2012). This solution is suitable for the lifestyle of the tribe, who always keep a fire going to cook food and keep animals at bay.

4.2 Software

Our Anti-Poaching application was built on top of a modified version of ODK Collect and to tackle the literacy issue we used a decision tree with pictorial icons as in an earlier project (Lewis, 2012; Lewis and Nkuintchua, 2012). The icons represent different signs of poaching activity (e.g. camps, footsteps, hidden weapons, traps, and so on), cases of abusive or corrupt behaviour by eco-guards, and sightings of live animals and other natural resources.

In order to make the icons comprehensible and relevant to the Mbendjele, they were designed according to

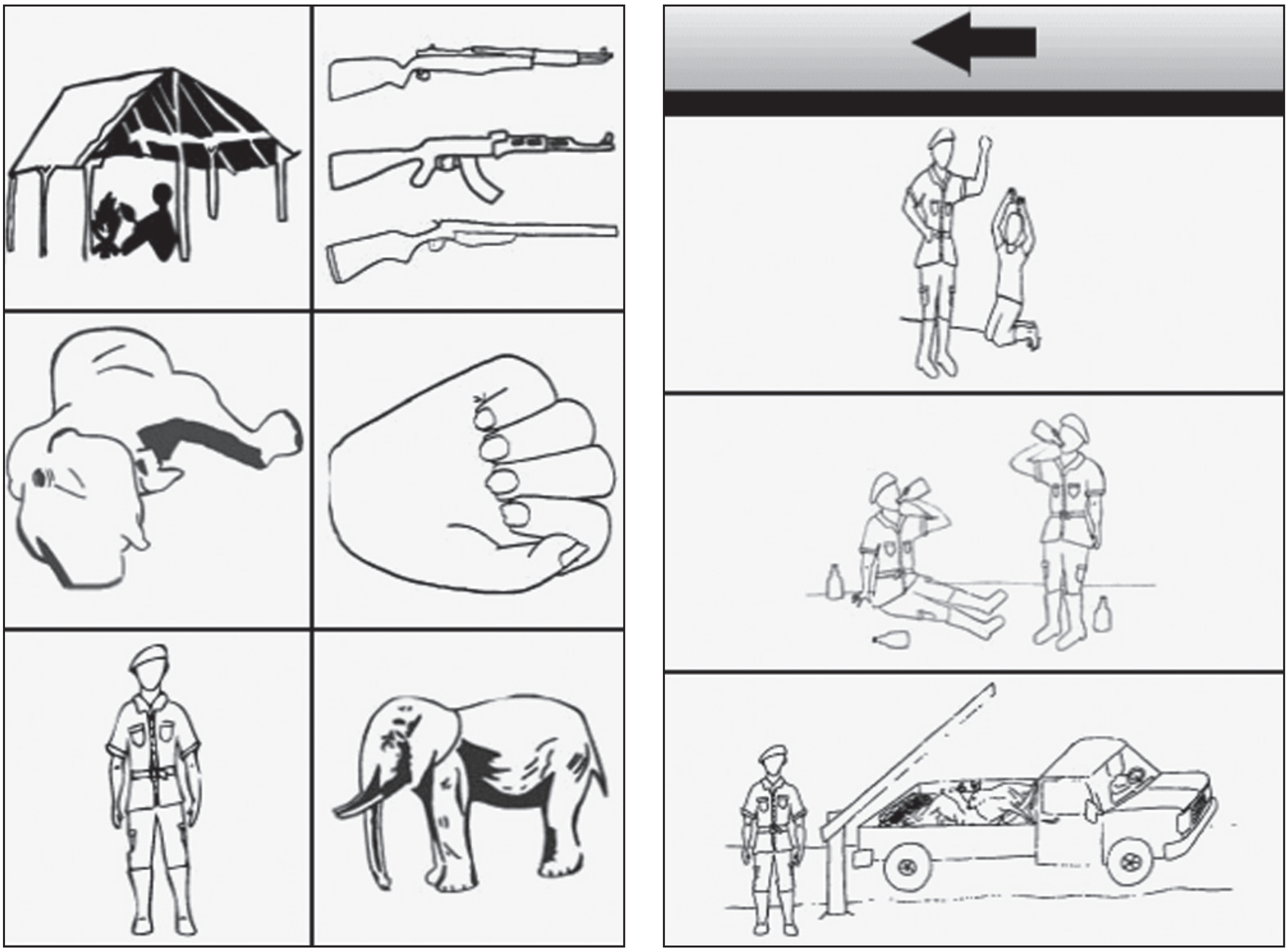

Figure 1 Main menu interface (*left*) and lower level interface (*right*)

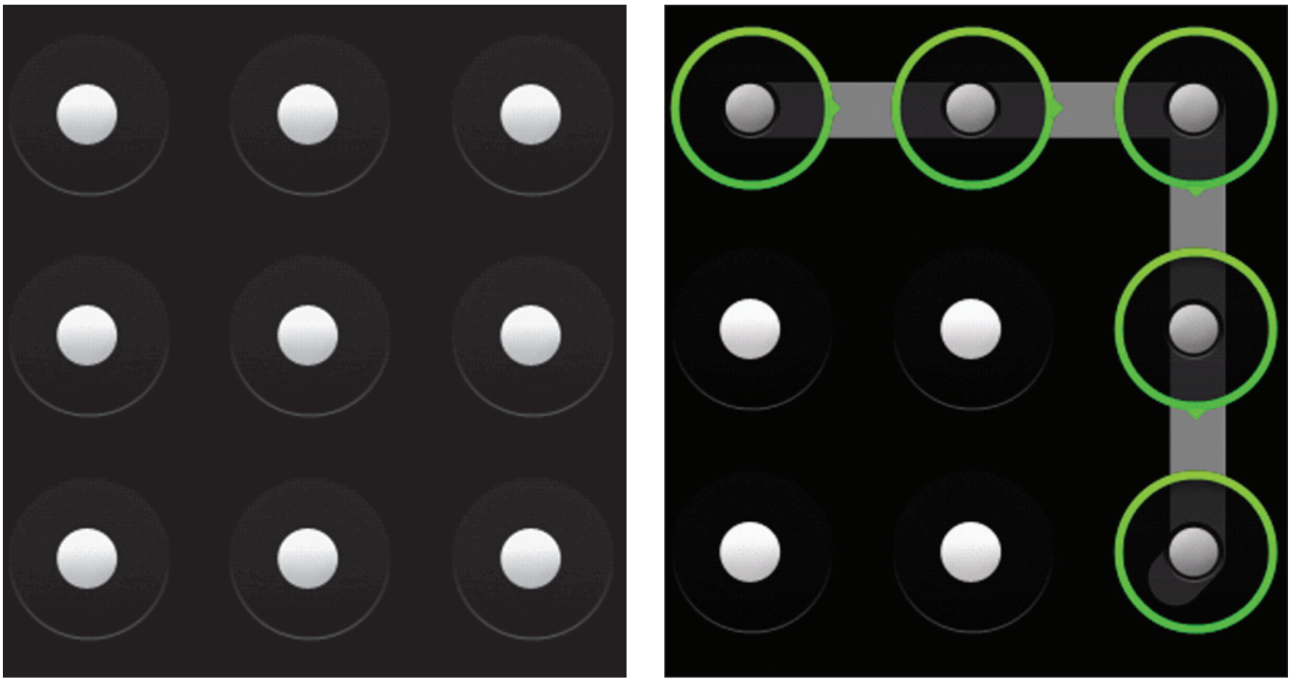

Figure 2 Opening screen, as locked (*left*) and unlocking pattern (*right*)

their feedback in a clear, smooth style, using only black and white. To avoid confusing or distracting the users, we modified ODK to not display any textual information and to operate in full screen (to hide the Android status bar, shown at the top of the screen, which provides information on the time, battery status, and so on). What is left is a minimalistic, entirely graphical interface in which the icons are arranged in a grid, as shown in Figure 1.

In the current version the decision tree consists of 59 distinct icons spread across four levels. Every observation starts with the main menu (shown in Figure 1, left); the user can navigate to a lower level by touching one of the icons and is then presented with a new, more specific set of choices. At every level except the top level, a back button allows users to go back one level (shown in Figure 1, right). When the user has reached the bottom level of the tree this means a complete, specific observation was described, and at that point the observation can be optionally complemented with an audio recording, a photograph, or a video. Afterwards, the device will try to obtain geographical coordinates from the built-in GPS receiver to geo-tag the observation. When the coordinates are obtained, the observation (along with multimedia attachments and coordinates) is automatically saved to the memory card of the device and a sound (a beep) indicates that the process is complete. The application operates in a continuous loop, meaning that at the end of each complete observation it goes back to the main menu, ready for the user to make a new observation.

It is important to restrict access to the application, so that the true purpose of the device can be hidden or denied. Due to the illiteracy of the users, conventional authentication mechanisms such as passwords and PIN (Personal Identification Number) codes are not suitable. Instead, we use a pattern unlocking mechanism, which many Android users are familiar with. When the application is opened, the user is first presented with a screen as shown in Figure 2 (left) and to proceed the user must draw a previously agreed pattern by sliding a finger over the dots on the touchscreen, as shown (right). If the pattern is recognized, the user will be presented with the main menu. The mechanism is used to restrict access to our application, rather than to the device itself, so that other ‘innocent’ functions of the smartphone remain unobstructed.

By default, ODK relies on the standard Android applications for audio recording and the photo/video camera. These interfaces contain textual elements and a plethora of features and settings which are confusing and distracting for the intended, non-literate users. Hence, we have implemented a minimalistic audio recording interface, shown in Figure 3 (left), where recording is represented by a microphone (a familiar concept to some members of the tribe due to the local radio station interviews). We have not yet created a replacement for the standard photo/video camera application but plan to do so in the near future.

Making observations of (possibly active) poachers’ camps presents the obvious risk of being spotted or caught. Thus we have implemented an innovative feature that allows users to point the device in the direction of the camp and provide an estimate of its distance away from the observer. The combination of the user’s own position (obtained through GPS), the bearing (registered using the built-in compass), and the estimated distance, allows us to compute the approximate position of the camp. However,

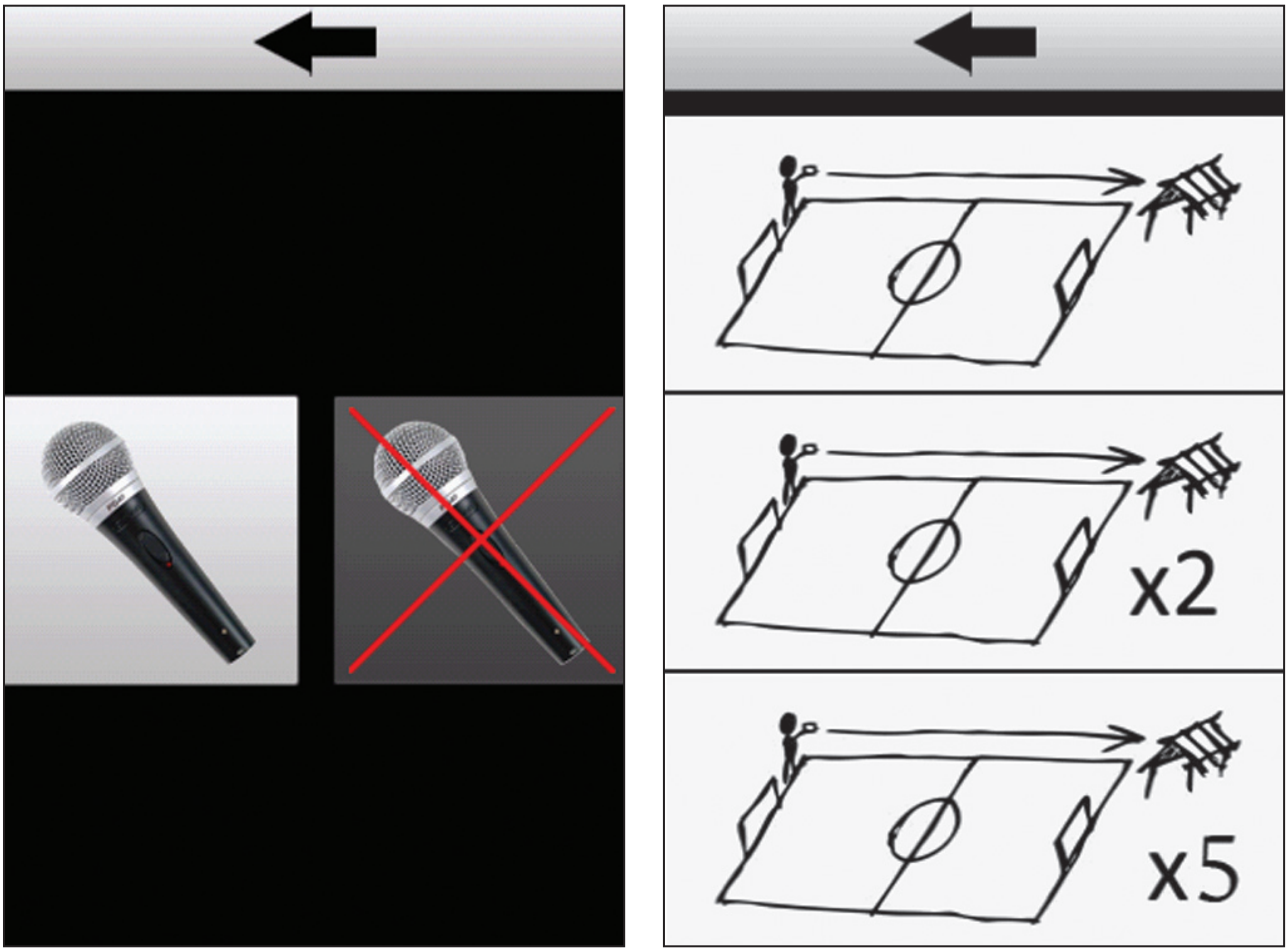

Figure 3 Audio recording interface (*left*) and distance estimation interface using football pitches (*right*)

our users are unfamiliar with standardised distance units and have no (or limited) numeracy skills for expressing distance. Therefore, we allowed distance to be expressed in terms of football pitches; a familiar feature to the Mbendjele, who have seen them in logging towns. As illustrated in Figure 3 (right), the UI allows users to select a distance of one, two or five football pitches. Few Mbendjele can read numbers, but we know that the specific individuals who will do most of the data collection can recognize the numbers 2 and 5 from handling 2,000 and 5,000 CFA (Coopération financière en Afrique centrale) banknotes – something not all their peers have had the opportunity of doing very often. Although this method is not very accurate in terms of distance, it nevertheless allows us to record a reasonable indication of the position of potentially dangerous places, so that eco-guards can find them.

5 Evaluation

Over the course of April 2012, our prototype platform was tested by the Mbendjele (coordinated by Jerome Lewis).

5.1 Hardware

We provided the Mbendjele with a set of four Samsung Galaxy Xcover smartphones and we also supplied them with a Hatsuden Nabe unit, a roll-up solar panel, and an auxiliary battery.

Results from using the smartphones have been promising; the devices proved to be robust, they withstood the dust and humidity of the forest as well as (mis)treatment by their users. Gorilla Glass screens proved to be as tough as promised, considering the smartphones were left without even the faintest scratch and were easy to operate, as the users quickly learned how to use the touchscreen. The built-in GPS receiver also proved to be adequate; in clear areas it took up to two minutes to obtain a first fix, and up to five minutes under forest cover. Obtaining subsequent fixes only took 10–25 seconds in most cases. Finally, we were impressed by the battery life of the smartphones; with ordinary use they could last for several days. However, people discovered they could use the smartphones to record their music and as torches during the night, causing dramatic battery drain.

The Hatsuden Nabe proved to be the most appropriate power source for recharging the smartphones, although it performed worse than the solar panel; it takes approximately 3–4 hours to fully recharge a smartphone, during which the water in the pan needs to be replaced up

Figure 4 Charging a smartphone with the Hatsuden Nabe HC-5

to six times (Figure 4 shows the pan in use). The tests were conducted with the Hatsuden Nabe HC-5, which has a diameter of 14 cm. In future, we may switch to one of the larger models to enable faster recharging. With the solar panel in direct sunlight it took about two hours to recharge two smartphones at once. As expected the solar panel turned out to be an excellent solution when sedentary in an open space, but is impractical while on the move or when under dense canopy. Some Mbendjele seemed to have no difficulty in executing tasks such as connecting the smartphones for charging or understanding the lack of power from a flat battery, while others required more coaching and repetition to become familiar with these tasks.

5.2 Software

Due to the secrecy of the project it was not possible to train as many users as we would have liked for software testing. Nonetheless, the Mbendjele collected a total of 427 observations, 151 photographs and 40 audio recordings during the training. Figure 5 shows one of the users recording an observation. Because this was the first evaluation of the platform, no risks were taken and hence the data does not reflect actual poaching activity. After the devices had been returned, we extracted the data and made an initial visualization using Google Earth. Figure 6 presents a sample of the observations.

The users who received training quickly grasped the concept of the decision tree, using the pictorial icons to represent observations, and overall, in working out what each icon represented. They seemed to like the beep sound that signalled the successful completion of an observation, although they would prefer a sound like a bird call or some other natural sound that would be less startling in the rainforest.

The users had little difficulty in learning how to use the pattern mechanism to unlock the smartphones, and while some found this confusing at first, after some guidance and repetition they quickly learned to master this task.

The audio recording part of the application was very popular among the users and they worked out how to use

Figure 5 A user recording an observation

this much easier than the camera. While audio recording was used extensively by the Mbendjele during an unsupervized 24-hour walkabout, the photographic application was difficult for those that were not used to two-dimensional representations. However, when using this was likened to operating a gun, i.e. "aim, hold firm, and fire", their usage improved. Some common issues included putting fingers in front of the lens, not holding the device still, and not coping with the slight delay between pressing the shutter button capturing the actual picture. The Save button was the most difficult aspect to grasp and generally impossible for most, confirming the need to replace the standard camera interface with a simpler, text-free one. The quality of the camera itself is adequate: the pictures look clear and vibrant and are reasonably sharp, except when taken in low light conditions.

Finally, the users seemed to have no difficulty understanding the concept of pointing the smartphone in the direction of a dangerous place in order to record the position from a distance. Individual tribe members that will conduct most of the data collection were indeed able to understand the concept of one, two and five football pitches.

6 Conclusions and Future Projects

Our Anti-Poaching data collection platform takes proven concepts (Lewis, 2012; Lewis and Nkuintchua, 2012) and adds innovative features based on the functionality of today's smartphones. Moreover, the use of alternative power sources vastly increases the flexibility of the platform. The initial evaluation phase demonstrates that the prototype works as expected but it also resulted in helpful suggestions for further improvements, which we will implement.

Our goal for the future is to create a more generic tool that could be used by different communities who wish to address issues of concern using tools and methods of scientific research. Ideally, people with limited computing skills should be able to design and deploy their own decision trees, suited for specific projects beyond our own. Enabling such flexible re-use will be one of the main challenges in the near future. Part of the solution will be to create a Web-based tool for designing decision trees.

Another challenge will be to implement a flexible means with which to transmit data to a central server. We intend to use a background service running on the smartphones which regularly checks for network coverage. The Mbendjele regularly visit small towns, or

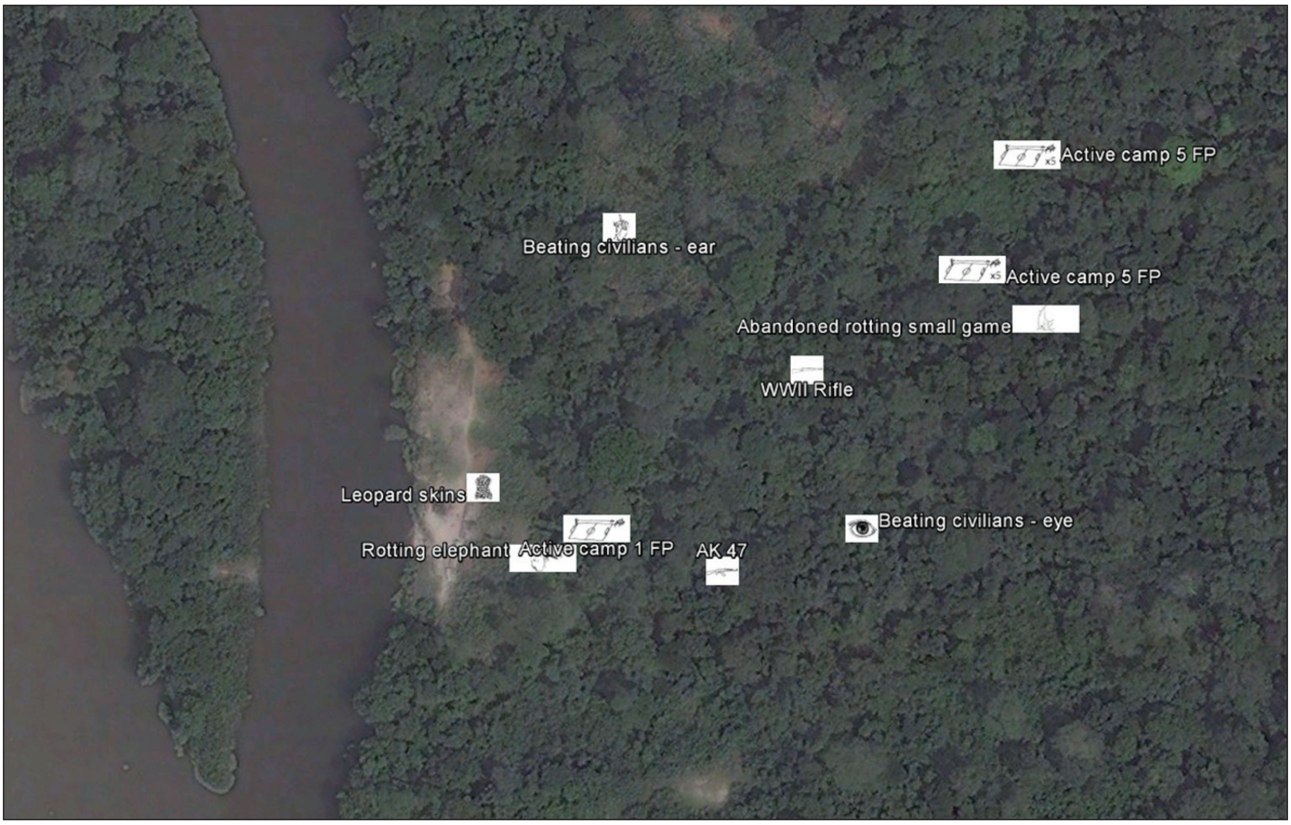

Figure 6 Initial visualization of observations in Google Earth

get sufficiently near to them, and the software must use this opportunity to transmit accumulated data. Transmission should happen automatically via SMS (Short Message Service), Wi-Fi (Wireless Fidelity) or GPRS/3G (General Radio Packet Service/3rd Generation), depending on availability, without any user interaction. The transmitted data will be compressed and encrypted to offer short transfer times and security.

In this article we have not covered the visualization and analysis aspects of the ExCiteS vision. We are currently working on a concept we call 'Intelligent Maps': a novel, dynamic approach to presenting spatial data and informing about emerging trends, both in ways comprehensible to illiterate people. This approach will allow non-literate users to visualize and better understand the environmental data that they have collected, helping them to address and state their concerns.

References

Aanensen, D.M., Huntley, D.M., Feil., E.J., al-Own, F. and Spratt, B.G. (2009) "EpiCollect: Linking Smartphones to Web Applications for Epidemiology, Ecology and Community Data Collection" *PLoS ONE* 4 (9) e6968

Anokwa, Y., Hartung, C., Brunette, W., Borriello, G. and Lerer, A. (2009) "Open Source Data Collection in the Developing World" *Computer* 42 (10) pp.97–99

Dickinson, J.L.and Bonney, R. (Eds) (2012) *Citizen Science: Public Participation in Environmental Research* Ithaca: Cornell University Press

Haklay, M. (2013) "Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation" In Sui, D., Elwood, S. and Goodchild, M. (Eds) *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice* Dordrecht: Springer Netherlands (pp.105–122)

Hartung, C., Anokwa, Y., Brunette, W., Lerer, A., Tseng, C. and Borriello, G. (2010) "Open Data Kit: Tools to Build Information Services for Developing Regions" *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development* (London, 13th–16th December, 2010) New York: ACM Article No.18

Hopkin, M. (2007) "Conservation: Mark of respect" Nature 448 (7152) pp.402–403

Imperial College London (2009) *EpiCollect – Mobile/Web Application for Smartphone data collection* Available at: http://www.epicollect.net/ (accessed 09/11/12)

International Electrotechnical Commission (2012) *IEC 60529: Degrees of Protection Provided by Enclosures (IP Code)* Geneva: International Electrotechnical Commission

Lane, S.J., Heddle, N.M., Arnold, E. and Walker, I. (2006) "A review of randomized controlled trials comparing the effectiveness of hand held computers with paper methods for data collection" *BMC Medical Informatics and Decision Making* 6 (23) pp.1–10

Lewis, J. (2012) "Technological Leap-frogging in the Congo Basin, Pygmies and Global Positioning

Systems in Central Africa: What has happened and where is it going?" *African Study Monographs Supplementary* Issue 43 pp.15–44

Lewis, J. and Nelson, J. (2007) "Logging in the Congo Basin: What hope for indigenous peoples' resources and their environments?" *Indigenous Affairs* 2006 (4) pp.8–15

Lewis, J. and Nkuintchua, T. (2012) "Accessible technologies and FPIC: Independent monitoring with forest communities in Cameroon" *Participatory Learning and Action* 65 pp.151–165

Parikh, T.S. and Lazowska, E.D. (2006) "Designing an architecture for delivering mobile information services to the rural developing world" *Proceedings of the 15th International Conference on World Wide Web (WWW '06)* (Edinburgh, 22nd–26th May, 2006) New York: ACM pp.791–800

Pundt, H. (2002) "Field Data Collection with Mobile GIS: Dependencies Between Semantics and Data Quality" *GeoInformatica* 6 (4) pp.363–380

Samsung (2011) *Galaxy Xcover (GT-S5690)* Available at: *http://www.samsung.com/uk/consumer/mobile-devices/smartphones/android/GT-S5690KOAXEU/* (accessed 09/11/12)

Stevens, M. (2012) "Community memories for sustainable societies: The case of environmental noise" PhD Thesis, Vrije Universiteit Brussel

TES NewEnergy Corporation (2012) *Hatsuden Nabe Pan Charger* Available at: *http://tes-ne.com/PDF/WHC-E.pdf/* (accessed 09/11/12)

Biographies

Michalis Vitos is currently a PhD student at UCL ExCiteS group. The objective of his research project is to develop innovative GIS tools that can be used by semi-nomadic and non-literate indigenous communities to capture environmental knowledge in methods that can be efficiently shared and assist them in the control of their land and resources.

Matthias Stevens is a computer scientist and works as a postdoctoral researcher at the UCL ExCiteS group. His research interests include citizen science, participatory sensing, and public participation in environmental resource monitoring and management. Before joining UCL he obtained a PhD from Vrije Universiteit Brussel in Belgium, with a thesis on concept of *community memories* and its application in a system for participatory monitoring and mapping of noise pollution, called *NoiseTube* (Stevens, 2012).

Jerome Lewis began working with Pygmy hunter-gatherers and former hunter-gatherers in Rwanda in 1993. This led to work on the impact of the genocide on Rwanda's Twa Pygmies. Since 1994 he has worked with Mbendjele Pygmies in Congo-Brazzaville researching child socialization, play and religion; egalitarian politics and gender relations; and language, music and dance. Studying the impact of global forces on many Pygmy groups across the Congo Basin has led to research into discrimination, economic and legal marginalisation, human rights abuses, and to applied research supporting conservation efforts by forest people and supporting them to better represent themselves to outsiders.

Muki Haklay is a Professor of Geographic Information Science at the Department of Civil, Environmental and Geomatic Engineering, University College London. He is the Director of the UCL Extreme Citizen Science group, which is dedicated to allow any community, regardless of their literacy, to use scientific methods and tools to collect, analyse, interpret and use information about their area and activities.