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Digital Technologies in Nature

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This workshop explored the design and deployment of digital technologies in nature. We sought to facilitate interdisciplinary dialog to explore how technology use may impact wildlife and change relations between humans, wildlife, and the environment, as well as to identify current design challenges and future opportunities for technology use in nature. Participant presentations shared uses of technologies for ecology, conservation, education, advocacy, and artistic engagement with nature. Through presentations and discussions, we explored opportunities and challenges associated with expanding deployment of sensors, drones, and mobile technologies in the natural world. Designing for natural settings requires collaboration between researchers and practitioners in fields such as animal-computer interaction (ACI), human-computer interaction (HCI), ecology, environmental psychology, arts, conservation technology and environmental management, as well as meaningful inclusion of local communities and non-human stakeholders. As an output of this workshop, we aim to establish a venue for interdisciplinary discussion on the challenges, tensions and ethical issues that arise in designing digital technologies for natural environments.

CCS CONCEPTS • **Human-centered computing→Human computer interaction (HCI);**

Additional Keywords and Phrases: Environmental sensing technology, Nature HCI, Ecology, Conservation technology, Animal-computer interaction, Sustainable HCI, Wildlife, Environmental psychology.

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1 INTRODUCTION

Rapid advances in sensor networks, wearable tracking devices, machine learning, pervasive computing and remote sensing technologies are transforming the ways that people engage and work with wildlife and their habitats. For ecological science, environmental management and conservation, these technologies may have a valuable role to play in collecting data from sites which are remote or difficult to access, and with minimal disturbance. Automated technologies for capturing and analysing wildlife data promise to reduce the time and effort required for ecological monitoring. With the emergence of off-the-shelf products such as AudioMoth audio recorders, and computer-vision platforms for conservation sponsored by industry giants such as Microsoft and Google, such technologies are being rapidly deployed worldwide.

Members of the public are also using technologies in diverse ways in nature. Spending time in nature for outdoor recreation, such as hiking, biking and camping, is now facilitated by handheld technologies, mapping and GPS location services, when locating and following trails. An increasing number of smartphone applications and other digital devices are now available that promote engagement with nature, environmental education and public participation in the study of nature, i.e., citizen science. Emerging digital technologies have the potential to contribute to a range of work and livelihoods in natural settings and remote areas, including search-and-rescue and production activities such as forestry and harvesting.

Despite the broad, cross-disciplinary interest in this topic, there has to date been little joined-up investigation into digital design and deployment impacts of digital technologies for natural settings. Researchers in the field of human-computer interaction (HCI) have investigated relevant technologies for people to engage with nature in their local area or woodlands, and participate in citizen science activities, for example. Meanwhile, animal computer interaction (ACI) scholars and wildlife management researchers have investigated the design of technologies to be used by wildlife and non-domesticated animal species. In other fields, there is substantial interest in how digital technologies are shaping ecological science and human relations with nature, but to date there has been little interaction between these areas of enquiry and the HCI and ACI communities.

It is evident that the field of ACI has much to contribute in this domain. ACI discourses on overcoming anthropocentrism in design and methodological advances to include non-human animals with human stakeholders in participatory design may provide a valuable foundation. Similarly, ACI's understandings of how digital technologies can impact animal behaviour and human-animal interactions are of broad relevance to the design of technologies for natural settings.

This workshop explores the opportunities and challenges associated with designing digital technologies for nature. Workshop participants include practitioners and researchers from fields such as interaction design, computer science, ecological sciences, environmental social science, wildlife management, and technology engineering. We survey current and emerging uses of technologies in nature, investigate associated ethical issues and potential impacts, and advance ACI discourses regarding the challenges of designing with and for more-than-human stakeholders. Outputs of this workshop will further strengthen ACI as a field which constructs interdisciplinary understandings for interspecies technology design.

2 BACKGROUND

2.1 Digital technologies for ecological science and conservation

In recent years there has been rapid uptake of digital technologies for ecology and conservation. This has resulted from expanding capabilities and reducing costs of technologies such as drones, machine learning for image and audio analysis, sensor networks and remote sensing. Example applications of these technological advances include the use of computer vision to automatically identify and count wild animals in camera trap images [39], use of drones in bushfire response [1,9], automated aerial seeding as part of reforestation [40] and classification of animal behaviour using wearable trackers [26].

Despite the enormous opportunities for advancing ecological science and facilitating conservation work, this introduces several challenges which warrant close attention and careful design responses. There is some concern about the ways in which sensor technologies are shaping our environments and human-nature relations [24]. ACI researchers have drawn attention to the animal welfare risks and ethical issues introduced by sensors, including through electromagnetic, light, sound and olfactory emissions [42]. Wearables may furthermore impact comfort as well as communication and predator / prey awareness [43] and require capture-and-release, perhaps repeatedly for ongoing device maintenance and battery replacement, which risks animal injury, stress and even mortality [5]. There is considerable evidence that drones can cause behavioural disturbance to wildlife if not deployed with care [48]. There are also calls for more attention to human social risks of deploying drones for conservation, including privacy, social acceptance and impacts on public understanding of conservation issues [49]. Capturing geospatial data about wildlife presents security challenges as such data can facilitate poaching if it is not carefully protected [22]. Consequently, ecologists and technologists have begun to explore how digital technologies can be applied strategically to realise proposed conservation outcomes [28], identifying that global leadership for interdisciplinary collaboration is essential to effectively inform efforts to save wildlife and habitats [35].

2.2 Digital technologies for living and working in nature

Technological interventions are being introduced into, and impacting on, other forms of work and livelihoods in natural settings. Given historical failures to include local and indigenous communities as stakeholders in conservation initiatives [18], it is essential to consider potential impacts of ecology and conservation technologies on local populations [6]. One area of concern in deploying sensing technologies is the potential impact of automatically capturing and analysing data about sites, animals and plants which might have cultural or spiritual significance to indigenous peoples. Designing information technologies in such settings may require negotiation between Western knowledge systems and indigenous ways of knowing [11]. There is a need for close consideration

of how scientifically motivated data collection may in some cases conflict with indigenous cultural imperatives to protect certain forms of knowledge.

National parks' visitor management and research might take greater advantage of visitors' growing use of smartphones [44,54], and such applications warrant further collaboration between ecologists, designers and visitor studies scholars. Increased use of digital technologies in disaster response in remote areas, including Search and Rescue, has received some attention from the HCI and ACI communities [29,61]. However, the use of mobile and sensing technologies as part of safe exploration of remote areas is in its infancy.

Management and protection of wildlife might also be aided by smart technologies to support rehabilitation and release of rehabilitant animals [34,38]. There is considerable interest in the role that sensor networks and artificial intelligence can play in detecting and averting wildlife poaching [31]. However, further investigation is required to examine how such systems can successfully integrate with rangers' existing anti-poaching work. For communities that live and farm alongside wild animals, automatically detecting and deterring wildlife might mitigate human-wildlife conflict and thereby reduce wildlife killings [14,51,62]. However, designing for long term success of deterrent systems requires a holistic design approach which addresses animal behaviour and ecological factors [13], as well as social and political factors [16].

2.3 Digital technologies and public engagement with nature

In recent years, HCI scholars have taken interest in how digital technologies can promote public engagement with nature [25]. Digital technologies such as smartphones are now widely used in hiking and other forms of nature-based recreation [2,27]. There is more to learn about how this impacts on various dimensions of people's time in nature, such as developing skills for navigation, and the experience of solitude [2]. Mobile mapping technologies have the potential to increase hikers' mobility [50] and the potential impacts on protected areas are not yet well understood [37]. There has been extensive interest in mobile applications to promote learning about nature [4] and for enabling the public to contribute, as citizen scientists, to ecological work aligned with Sustainable Development Goals [23]. Public use of automated sensing devices, including cameras and audio recorders, have the potential to foster awareness of nature such as birdlife [52,57]. Observations, photographs, and audio recordings of nature collected by the public [46] are often used to train artificial intelligence and contribute to scientific investigations, and can inform conservation actions [10].

Though many such interventions target urban communities and settings [12,19,52,57,59], there is increasing attention to designing with people who visit or live in remote places, for nature awareness [15], citizen science through photographic capture [47] and for participating in ecological monitoring [58]. However there remain concerns about unequal public participation in activities such as environmental monitoring, along geographic, economic and cultural lines [3]. Designers of such interventions should heed calls for more attention to conservation outcomes and analysis of design factors [3], and are cautioned against assuming that attitude change will translate to behavioural outcomes [17].

In designing technologies for public use in nature, a broad challenge lies in the potential for digital devices to interrupt or distract from immersive experiences of the natural world. This issue intersects with concerns about young people's "screen time" and digital devices as a barrier to family bonding experiences, which come to the fore in outdoors settings [32]. There are also some fears that technologically-mediated nature and simulated nature may come to replace opportunities to directly experience the natural world, with potentially devastating effects for people's connectedness with nature [30,45,56]. These concerns demand careful design approaches to develop

forms and uses of technologies which can strengthen connections with nature rather than curtailing, commoditising, or supplanting them.

2.4 Designing with wildlife and natural environments

It is clear from the above that designing for nature demands approaches and solutions which can account for divergent perspectives and conflicting needs. Interaction design methods [36], including "research through design" [53] provide fruitful approaches to address "wicked problems" [63] and "design paradoxes" [17]. These methods are now widely used in user-centred technology design and product development. An important contribution of such methods is to understand the influences, requirements and constraints of the contexts in which technologies are used. In designing for nature, there is a need for grounded understandings of the sociocultural factors and organisational practices that impinge on technology use and design [15,41]. There is also a need to understand how instances of technology use are situated in ongoing timelines such as long-established cultural connections to country, connections to nature as part of social identity, the workflows of ecological science and long-duration conservation interventions.

The ACI community has proposed ways in which interaction design methods can be adapted and extended to include non-human animals as stakeholders whose needs are centred, and even as active participants in the design process [20,21,60]. Such work points to the value of collaborations which extend beyond a single 'domain expert' working with designers. For example, ACI projects which bring together multiple disciplinary specialists on topics such as animal biology, behaviour, cognition, husbandry and social sciences allow for nuanced design, grounded in an understanding of competing perspectives and alternative intervention strategies [60]. ACI approaches to adapting interaction design methods have provided a point of departure for considering how such techniques can be further expanded to include the concerns of the biosphere and of ecosystems in design [33,55]. Such efforts resonate with those who call for inclusion of more-than-human concerns and voices in sustainable design [12] and in participatory research [8]. However, much remains to be done to integrate interaction design, ACI methods and more-than-human participation with theory and methods from disciplines such as ecology, conservation and environmental psychology, and with environmental management practices.

3 AIM & OBJECTIVES

Through this workshop, we aimed to explore contemporary uses, existing challenges, and design opportunities for technology in nature. We did this with the vision of developing an interdisciplinary research agenda for understanding and designing digital technologies in nature.

Our workshop objectives were to:

1. facilitate networking between different communities of researchers and practitioners interested in digital technologies in natural settings;
2. discuss ethical considerations and unintended impacts relating to humans, animals, and ecosystems when designing technologies for use in nature;
3. investigate approaches to designing and evaluating digital technologies for this context;
4. explore how cultural values, worldviews, and attitudes to nature can influence design.

4 CALL FOR PARTICIPATION

The call for participation was published online and advertised via social media and mailing lists. Potential participants submitted an expression of interest, outlining their interest in the topic and optional talk pitch.

Workshop on Digital Technologies in Nature at ACI'21 Conference. 9-10 Nov 2021.
In natural settings we are making increased use of digital technologies such as sensors, AI-powered smartphone apps, wearables for animals, smart camera traps, acoustic sensing, drones, remote sensing, GPS-based mapping and navigation - and much more. These technologies are being used for ecology and conservation, livelihoods and management of parks and remote areas, outdoor recreation and public engagement.

We believe that more interdisciplinary collaboration is needed for successful use of digital technology in nature, and to understand and minimise potential impacts and issues. In this workshop we aim to build networks of researchers and practitioners, and bring different perspectives and expertise to discussions about the challenges, opportunities and risks of these technologies, including:

- animal welfare impacts and other effects of wearables, sensors and drones
- how sensor technologies may be shaping environments and human-nature relations
- considerations of capturing data about natural features of cultural or spiritual significance to Indigenous peoples
- privacy and security of biotelemetry and geospatial data
- how people's time in nature is altered by the presence of technology (e.g. experience of solitude)
- inequality of access and participation in nature-related activities
- risks that "digital nature" might result in fewer rich, immersive, direct experiences of the natural world.

5 PROGRAM AND ATTENDEES

We recruited potential speakers and workshop attendees from our diverse interdisciplinary and professional networks. To be globally inclusive, we invited potential participants to attend one of two online sessions spaced 15 hours apart. From submissions, we selected 20 speakers (10 per session) to deliver short talks (3-5 mins), and invited others to attend one or both sessions. Each session began with short talks and questions for speakers. We then conducted two rounds of small group conversations followed by whole group discussions. Discussions addressed the following questions:

1. How could the technologies you use potentially change how people interact with nature?
2. What adverse impacts should people consider when using tech in nature?
3. How do you decide on what technology you use in nature?
4. What are cultural factors and values that shape tech use in nature?

The workshop was attended by 64 participants, with interests spanning ACI, HCI, ecology, wildlife conservation, citizen science, computer science, bioacoustics, acoustic ecology, animal welfare, animal policy, conservation technology, cultural geography, environmental psychology, education and advocacy, nature art, nature music, and technology development.

Presentations and discussions revealed that people are engaging in many different ways with the challenges of using technology to understand and engage with nature. Within the diversity of responses to the workshop themes, we identified some striking commonalities in the issues and considerations that participants brought to conversations. For example, the challenges of using technology to shape public attitudes and behaviours towards nature are a topic of interest for people working in many disciplines. Concerns about the environmental impacts of computing hardware and associated resource extraction came to the fore, as well as potential negative impacts on wildlife and human-nature relations. At the forefront of discussions on design and evaluation of technology were the constraints of cost, skills and practical considerations, alongside the desire for meaningful collaboration with local communities and consideration of non-human stakeholders. Here we provide a glimpse of just a few of the topics discussed. Our plan is to prepare and share a comprehensive account of the powerful and inspiring cross-disciplinary discussions that occurred, with the goal of informing the design of digital technologies in nature and fostering interdisciplinary collaboration.

We will submit an article outlining the research agenda to be distilled from this workshop. Additionally, we intend to draft a report of workshop findings for a broad, cross-disciplinary and professional readership. We will also explore ways to foster ongoing discussions between participants and broader professional groups interested in the intersections of technology in nature. Future outputs will be shared through the workshop website at www.ozaci.org/nature.

6 ORGANISERS

6.1 Sarah Webber

Sarah Webber is an interaction design researcher at the University of Melbourne who investigates how digital technologies can better respond to contemporary values in areas of human-nature relationships, social connectedness and wellbeing. Her research focuses primarily on technologies for connections with nature and wildlife, and how digital designers can respond to animal welfare and associated ethical issues. Her award-winning PhD research, conducted in collaboration with Zoos Victoria (Melbourne Zoo), examined the design of an interactive installation, and impacts on orangutan wellbeing and visitor engagement. She has a professional IT background spanning user research, UX evaluation, business analysis and project management in corporate, non-profit and governmental organisations.

6.2 Jessica L. Oliver

Jessie is a PhD student at the Queensland University of Technology studying how to design enticing technologies that support people connecting with nature. Her research at present explores, in particular, how to design enjoyable interactions with media about nature that supports people to learn about and identify wildlife vocalisations from audio recordings. Before delving into design research, Jessie studied wildlife and their habitats, as well as taught people about the natural world, in a variety of ecologist and environmental educator roles. With a passion for empowering members of the public to engage with science and conservation, Jessie has been heavily involved in the development of the Australian Citizen Science Association (ACSA) as well. As a consultant, and in her role as ACSA International Liaison, Jessie has also contributed to diverse research and initiatives. These have explored intersections of citizen science with technology design, wildlife conservation, conservation technology, environmental health, environmental education, and sustainability policy.

6.3 Wally Smith

Wally Smith is a member of Human-Computer Interaction group in the School of Computing and Information Systems at the University of Melbourne. His research investigates the theory and principles of designing new digital technologies that are sympathetic to human ways of thinking, living and working across a range of settings. His recent projects investigate deceptive AI, digital emotion regulation, citizen heritage, and digital tools for smoking cessation. He is a past National Secretary of CHISIG (the Australian Computer-Human Interaction Special Interest Group of the Ergonomics Society of Australia), lead creator of the PastPort citizen heritage site, and co-editor on recently published Routledge International Handbook of New Digital Practices in Galleries, Libraries, Archives, Museums and Heritage Sites.

6.4 Helena Bender

Helena Bender is a behavioural ecologist who now undertakes interdisciplinary research and is a teaching specialist in the School of Ecosystem and Forest Sciences at the University of Melbourne. Her research includes wildlife management with sound, the theory and practice of sustainability, practices to improve integration of social and biophysical sciences in social ecological systems work, and the many disciplinary meanings of hope and its role in the Anthropocene. Her recent interdisciplinary work has elevated consideration of the ethical ramifications of technical solutions at different scales, whether that be kangaroos on roadways, or bats in botanic gardens.

6.5 Kellie Vella

Kellie Vella (Queensland University of Technology) is a human-computer interaction researcher with an interest in the overlap between technology, sociality, wellbeing, and sustainability. She draws upon theories and methods across the humanities (in particular, social and motivational psychology, ethnography, and participatory research) to better understand how to design, apply, and evaluate technologies. Currently, she is researching ways to connect people with their local ecology through ambient technology (Ambient Nature Network); collaborating with Green Music Australia to reduce festival campsite waste; and project managing the development of an open ecoacoustics data platform.

6.6 Margot Brereton

Margot Brereton is a national and international leader in the collaborative design of new humanitarian technologies and their interfaces. She designs with real user communities whose needs are typically overlooked in technology development. She has focused on better futures for and the agency of older people, people with intellectual disabilities, connecting people to nature, and fostering use of endangered Indigenous languages.

Margot works with particular communities in long term engagements over several years to ensure that designs fit into people's lives in positive ways with people shaping their evolution. Margot's approach, which focuses on tangibles, connected interfaces, AI and machine learning technologies, leads to innovative designs and new theoretical understandings and methods in the field of Human-Computer Interaction. Margot is Professor of Engineering and Interaction Design in QUT's School of Computer Science and Director, Research Performance at QUT's Institute for Future Environments. She has served on the Australian Research Council College of Experts. Margot has raised over $6 million in competitive grant funding, published more than 230 fully peer-reviewed papers and supervised 14 PhD students to completion. She began her career as an apprentice at Rolls Royce aircraft engines and holds a PhD in Mechanical Engineering Design from Stanford University.

6.7 Alasdair Davies

Alasdair Davies is a conservation technologist developing, designing and deploying conservation technologies globally. He is Technical Director of the Arribada Initiative, a Senior Technical Specialist and Advisor to the Zoological Society of London, and a Shuttleworth Foundation Fellow, with 14 years' experience developing, designing and deploying conservation technologies for conservation organizations globally, including the National Geographic Society and the World Wide Fund for Nature. His primary focus is the development of open source conservation technologies, with his most notable achievement the release of the first open source Argos satellite transmitter reference design for telemetry and biologging. Alasdair was awarded a Shuttleworth Foundation Fellowship in March 2017 and founded the Arribada Initiative to unlock access to open source conservation technologies, focusing on human-elephant conflict, low-cost telemetry, biologging, and passive acoustic monitoring technologies.

6.8 Julia Hoy

Julia Hoy is Research Manager at Hidden Vale Wildlife Centre, at the University of Queensland. Her research explores next-generation husbandry and captive management and technological advances in conservation. Current projects include microchip-automated technology in wildlife conservation, examining how such devices can be used by Australian native wildlife in reintroduction programs. In this work she explores applications of microchip-automated technologies such as tracking released animals, to enable animals to access food during reintroduction programs, or to take refuge as part of predator avoidance training programs.

6.9 Kate Judith

Kate Judith's recent environmental humanities PhD (UNSW), took a more-than-human perspective, exploring questions of being in-between through mangrove ecologies. Kate is interested in approaches that shift research and inquiry from anthropocentric interests. She teaches at the University of Southern Queensland.

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