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HCI Outdoors: Theory, Design, Methods and Applications

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Contents

Finding Human–Computer Interaction Outdoors

D. Scott McCrickard, Michael Jones, and Timothy L. Stelter

Abstract Human–computer interaction, as a discipline, has shifted from an examination of computers in controlled indoor environments to the study of technology use in a broader collection of settings, including the outdoors. This chapter seeks to explore the evolution of HCI outdoors as an area of study, seeking to identify the considerations that make it an important and unique domain. We begin by examining the tensions and opportunities that have long existed between technology and the outdoors, pointing to the unique position of HCI as a discipline for probing these issues. Using HCI as a lens, we then seek to understand what is meant by the outdoors, and how humans, computers, and their interaction together have evolved to a point that they can address issues of outdoor use. We introduce several seminal efforts related to the study of technology use in outdoor settings, including a collection of recent workshops and events that helped identify and bring together important ideas in the field. We conclude with a categorization and introduction of the chapters in this book on HCI outdoors. The chapters in this book present new theory, design, methods, and applications that will shape the emerging field of HCI outdoors.

1 Overview

As interactive computing pushes into outdoor activities, it is not clear what the role of this technology is or should be. It may seem odd to pair technology with the outdoors, as many look to the outdoors as a place to escape from technology. However, the benefits of using technology in outdoor situations hold promise for better experiences and better reflections after the experiences. People want to enjoy their outdoor experience, but to do so they may need information at the moment that

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technology can provide. Or they may be unable to fully experience elements of the outdoors without technology. Or they may wish to capture aspects of the outdoor experience for scientific or personal advancement. Or technology may guide them to experience something positive but which they had not intended to experience. Technology can help us learn, calculate, remember, share, coordinate, work, play, and more. But, as both designers and users of technology, it is important that we seek to understand ways to use technology that meet our goals and desires outdoors.

This book explores how human–computer interaction (HCI) can help us understand, define, realize, and evaluate the emerging role of technology in the outdoors. In the 1970s and 1980s, the earliest years of HCI as a discipline, HCI methods largely focused on single users and desktop machines, using quantifiable performance metrics like learning time, completion time, and error rate as most popular ways to measure success—with its methods melded from cognitive science, psychology, and computer science. The 1990s and 2000s saw the growth of HCI, to include broader definitions of humans, computers, and interactions, along with a wider range of methodological disciplines such as ethnography, sociology, art, and engineering. Within the last two decades, HCI has cast a wide net, seeking to shift from desktop and laptop machines to include mobile and wearable devices, and from direct interactions to include indirect and sensed ones. This evolution of HCI as a discipline positions it as a lens through which to examine technology outdoors, a domain for which a traditional desktop-based direct interaction examination would not suffice.

An important early consideration for the editors was to identify what was meant by the outdoors. It is difficult to describe the true nature of outdoors, or even to outline what it is and is not, so we sought to establish a spectrum of factors for which our methods would be increasingly applicable. As a way to ground these ideas, consider a typical office park setting, such as the one where the first editor has an office. There is a large picture window at his office that looks over a sculpted lawn, a pond with a fountain, and paved walking trails. The trails lead to the Huckleberry Trail, a rails-to-trails multi-use path. This in turn leads to Pandapas Pond, an 8-acre day-use area that permits hunting, fishing, mountain biking, and horseback riding. The pond is part of the Washington-Jefferson U.S. National Forest, a vast minimally developed tract of land that spans several states. The Appalachian Trail, a U.S. National Scenic Trail that spans over 2000 miles across 14 states, cuts through the forest. The Appalachian Trail passes through some small towns and other semi-developed regions, but it also traverses near or through 20 National Wilderness Areas[1]

Each step in this narrative, from viewing a sculpted outdoor setting to traversing an untamed wilderness area, adds different opportunities, challenges, and drawbacks to appropriate use of technology in increasingly unwelcoming—and sometimes unwelcomed—environments. To some degree, this is because the design of many technologies has been targeted for more urban environments, both in the nature of the hardware and in the design of the technology. As examples, mobile phones tend

[1] The United States Congress established National Wilderness Areas with the passage of the Wilderness Act of 1964. Wilderness areas are protected tracts of wildlands where "man himself is a visitor but does not remain."

to be hard to read in direct sunlight, and wearable cameras exhaust their batteries after only a few hours. Potential users must either seek to suffice with inappropriate technologies or look to craft better ones.

Taking a step back, to many authors and artists, the outdoors is a place of solitude that should be devoid of technology—even among people who otherwise are tech-engaged or tech-knowledgeable. Eric Brende left a career in technology after completing his MIT degree to live devoid of most technologies, detailed in his book Better Off (Brende 2004). Bestselling books like Richard Louv's Last Child in the Woods notes the loss of exposure to nature for children and points to the "myopic focus on high technology as salvation" as a reason why young people lack this exposure (Louv 2008). Popular writers like Bill Bryson, when he encounters a hiker with a weather sensing station, laments "How I hate all of this technology on the trail" (Bryson 1998).

Yet, it is often technology that positions an outdoor experience as unique, special, memorable, and even possible. Mark Twain's Huck Finn had his raft that enabled him to travel the Mississippi River (Twain 1885), and Steinbeck's Joad family had a vehicle (and the knowledge to keep it working) (Steinbeck 1939). Sometimes, it's the lack of technology that makes an outdoor experience special, viz., walking the 2000-mile Appalachian Trail barefoot (Letcher and Letcher 2008), and sometimes it is an excess of technology (sacrificing convenience and practicality for data, knowledge, and understanding) as seen in Alan Dix's tech-enhanced walk around the perimeter of Wales (Asimakopoulos and Dix 2017; Dix and Ellis 2015). Scientists, environmentalists, educators, and search and rescue personnel all rely on technology in outdoor settings. Recreation activities become more accessible because of technology, including and especially for those with special needs, and the ability to reflect is enhanced. And technology provides avenues to learn skills that otherwise are hard to acquire, including skills related to navigation, health, and safety.

So how do we identify the appropriate situations for technology, and the appropriate ways to present information and engage with tech users in outdoor settings? HCI provides theories, methods, and assessment techniques that may prove helpful in addressing these problems, though it is not yet clear which best applies. HCI, only about 30 years old, is still a young discipline that has experienced significant change as new interactive technologies emerge. HCI has its roots and in its name the understanding of the opportunities, tensions, and interaction styles that occur when humans and computers come together. The discipline has evolved from focusing on controlled lab situations to include the examination of the wild. Miniaturization of technology and advances in power and network connectivity have made possible a broad array of functionality in outdoor settings. This book seeks to highlight emerging research that demonstrates ways that HCI can play a role in understanding ways that humans and technology interact in the outdoors.

2 Topical Scope

We describe the topical scope of the book using a broad HCI-based framework. The framework can be used to describe and discuss technology use in the outdoors. We intend for this framework to be a starting point and expect that it will evolve and perhaps, eventually, be completely replaced. As a lens, HCI foregrounds four elements of technology used outdoors: one or more humans, a computer system, human interaction with the computer system, and being outdoors. Table 1 contains a definition, categorization schemes, and several examples for each of these four concepts. The remainder of this section describes each concept as it relates to the broad space of HCI outdoors. The chapters in this book begin to populate this space and provide examples of different directions for research and practice involving HCI outdoors. (This section bolds references to chapter authors, with first initials provided to clarify ambiguity.)

2.1 Outdoors

In simplest terms, the outdoors is "a place or location away from the confines of a building."[2] This definition includes a wide variety of outdoor settings ranging

Table 1 Four elements of human–computer interaction outdoors along a selection of categories and examples elaborated in this section. The categories and examples here exemplify the broad base that exists and is emerging for the study and practice of HCI outdoors

Outdoors	Definition: an environment which is not indoors and lacks the controls and amenities of the indoors, for which factors like weather and lighting are of particular concern Categories: climate, degree of human development Examples: public urban spaces, groomed ski slopes, rain forests, deserts, long-distance hiking trails
Human(s)	Definition: individual or group for whom physical, mental, and interpersonal issues affect the situation and the technology use Categories: individual characteristics include age, gender, vision, memory, height, dexterity, disabilities; group characteristics include connectedness, communication, conflict Examples: children, people with autism, hikers, skiers, environmental engineers, citizen scientists, 5-person rescue team
Computer(s)	Definition: electronic system consisting of programmable hardware or software Categories: form factor, connectivity, sensors, input/output modalities Examples: smartphone, smartwatch, haptics, VR/AR headsets, the internet
Interaction	Definition: ways that humans and technology connect and communicate Categories: direct manipulation, commands, conversations, notifications Examples: typing, clicking, scrolling, learning, speech, gestures

[2] As defined in the online edition of the Merriam-Webster dictionary.

from city streets to remote wilderness. When presenting or planning work involving HCI outdoors, it may be useful to describe the outdoor setting in some detail. This can be done using existing schemes that classify the outdoors based on climate and on the degree of human development, which seem to have a significant impact on HCI outdoors. We describe two well-known classification systems: the recreational opportunity spectrum (ROS) for the degree of human development and the Koppen scale for climate. Alternative classification schemes exist for both climate and human development, as can be found in a climatology textbook (Rohli and Vega 2017) and other research involving the degree of human development (Hill et al. 2002). Classification schemes also exist for other properties of the outdoors such as plant cover or for bodies of water.

We focus on climate and human development as they seem to have a significant impact on HCI outdoors. Climate describes the range of weather conditions found at a location over a period of decades. Climate and weather impact how a user interacts with a device outdoors. On a cold day in an arctic climate, interacting with a smartphone touch screen is difficult because the user must take off their gloves to touch the screen and ungloved fingers can quickly become numb. However, on a warm day in a temperate oceanic climate, interacting with a touchscreen is simple.

Human development outdoors refers to elements of the built or cultivated environment. Human development dictates the power and network resources that will be available and often shapes social context. For example, primitive settings lack power outlets that are abundant in urban settings. Even in rural settings, access to networks may be limited compared to urban settings. Human development influences what is acceptable or even desirable in a given outdoor setting. For example, constantly checking email could be seen as intrusive in a wilderness region but as part of the routine in an urban area.

The Koppen scale classifies regions of land based on climate and consists of 26 climates organized into 5 primary groups (Rohli and Vega 2017): tropical, dry, temperate, continental, and polar. Within a primary group, climates are distinguished by monthly average rainfall and temperature over a period of decades. Primary groups are denoted by the letters A through E and subgroups are indicated using one or two additional letters. For example, the Koppen climate "Am" is a tropical (A) monsoon (m) climate, and climate "Dsa" is a continental climate (D) with dry (s), hot (a) summers. Climates and seasons play prominent roles in several chapters of this book. **Häkkillä's** chapter takes place in a cold subarctic climate (specifically in Koppen zone Dfc) in the winter, and **Anderson's** case study is set in spring in a semi-arid climate (in Koppen zone Bsk).

The recreational opportunity spectrum (ROS) categorizes outdoor settings based on the evidence of human impacts. Human impact is measured by the presence of built facilities (such as buildings and indoor plumbing), access methods (such as roads or trails), and the presence of other people (Clark and Stankey 1979; United States Department of Agriculture Forest Service 1986, 2011). While the ROS was developed by the United States Forest Service, it has been used in other areas of the world (Joyce and Sutton 2009; Paracchini et al. 2014). There are six top-level classes in the ROS: primitive, semi-primitive non-motorized, semi-primitive motor-

ized, roaded natural, rural, and urban. Primitive settings normally lack built facilities, are not accessible by roads, and have few people present simultaneously. At the other end of the scale, urban settings have abundant complex facilities, are accessible by many well-maintained roads, and are often crowded with people. In this book, the degree of human development figures prominently in several chapters. For example, the chapters of **Balestrini** and **Aguiar** explore technology designed for urban environments, **Dix** and **Su** examine technology opportunities in rural environments, and **B. Jones'** studies technology supporting search and rescue in a primitive wilderness environment. **Alsaleem**'s sitski system has been used in several locations including testing at a ski resort in the Wasatch Mountains, Utah, USA. The ski resort is located in a high-altitude humid continental climate (zone Dfb) and was developed to become an urban setting in the ROS scheme.

2.2 Humans

The term human connotes many things, including abilities to think, reason, move, plan, communicate, and work together. In the short history of HCI, the concept of "human" has evolved considerably. The ACM SIGCHI Conference in the early 1980s primarily focused on single-user systems, in which a user in an office setting worked on focused, well-defined tasks with a clear end goal (e.g., remembering command names, editing text documents, navigating graphical interfaces). Measures of human performance focused on ways that people think, process, react to, and remember information, as well as on the physical work environment. The late 1980s and 1990s saw increased study of multi-tasking, ubiquitous computing, and computer-supported collaborative work (CSCW), examining how multiple people work together on many different tasks, using both computers in the traditional sense and technology on our persons and in our environment. During the 2000s, HCI has embraced a great many other fields, including art, architecture, geography, ethnography, sociology, and much more—each with its own ways of defining what it means to be human.

Core HCI textbooks and reference books focus on humans' abilities and characteristics, guiding designers to consider them in crafting and evaluating designs. In their widely used introductory textbook, Ben Shneiderman and his colleagues highlight the physical, cognitive, and perceptual abilities of humans, emphasizing the importance of considering cultural and international diversity, differences in personality, abilities and limitations due to age, and importance of considering users with disabilities (Shneiderman et al. 2016). Grudin notes the importance of considering perceptual, cognitive, social, and emotional characteristics of humans during design (Grudin 2017). Wickens et al. compare visual, auditory, and spatial factors for perception and attention in human performance (Wickens et al. 2015).

HCI practitioners and researchers employ user models to capture human characteristics viewed as most relevant to design. Generally, these user models are rooted in a data-centered understanding of the target user, toward ensuring that the design will meet the users' needs. For example, personas require designers to craft an archetype

user that captures specific needs, based on the analysis of user data, then revisit the persona constantly during design to help guide decision-making (Cooper et al. 2004; Pruitt and Grudin 2003). Common user characteristics that are captured in personas and other user models include name, age, occupation, hobbies, relationships, and more. Increasingly, the discipline of HCI has examined humans not only as individuals but also as part of a group, such as a couple, family, team, or community. Factors of the group, such as connectedness, communication styles, and desire to cooperate or compete, must be considered when investigating and designing for the goals and needs of the people—not just as individuals but as a group.

In considering the human component of HCI outdoors, the chapters of this book represent many different ways to understand and design for humans. For example, the perceptual, mental model, attentional chapter by **B. Jones** and his colleagues focuses on distributed cognition, exploring how people bring their collective knowledge and skills to a search and rescue situation, and how technology can contribute to that knowing and doing. In contrast, the chapter by **Patrick** and his colleagues consider physical characteristics of users, considering how bone conduction devices can help people better use their auditory senses. The chapter by **Neustaedter** and his colleagues explores the connectedness of groups of humans (families), and the chapter by **Polys et al.** looks at how groups of people come together with technology in scientific inquiry. Some chapters focus on a particular subset of humans, such as the chapter by **Fails and M. Jones** that studies outdoor interfaces for children and the chapter by **Al Saleem** and his colleagues that describes a snow skiing interface to support people with disabilities. The careful consideration of what it means to be human helps craft technology solutions that meet real needs.

2.3 Computers

Describing the notion of a computer within HCI is a moving target. In HCI textbooks, the term "computer" is often paired with other terms—like "[computer] technology," "computer/electronic device," or "[computer] system"—and includes a focus on input and output devices like the keyboard, mouse, and digital display (Bryant et al. 2016; Carroll 2003, 2013; Dix et al. 2003). However, HCI paradigms that include indirect interaction de-emphasize traditional input and output devices, focusing on a richer collection of sensors, haptics, audio, and more. For example, the notion of the third paradigm (Harrison et al. 2007) and Weiser's concept of calm computing (Weiser 1991) both feature a tighter partnership between the computer and the human-centered actions that are important to its use.

In considering these different notions of a computer, we identify form factor, input/output modalities, sensors, and connectivity as particularly important for HCI outdoors. When using a computer outdoors, the form factor enables certain kinds of interaction possible but precludes others. A large interactive kiosk on a city street invites a group of people to interact but can not be (easily) deployed in a remote rainforest. On the other hand, a handheld smartphone can be used easily in temperate outdoor locations but not in cold climates while wearing gloves. Similarly, input/output

modalities also determine what is possible or convenient when interacting with a computer outdoors. For example, handhelds and tablets are convenient on paved or even terrain, but they are challenging and dangerous on rough terrain. Sensors in the outdoors open a wide range of possibilities for direct and indirect interactions. Accelerometers and heart rate monitors in smartwatches allow devices to unobtrusively track steps taken, stairs climbed, and activity levels, while the user focuses on an outdoor activity. Connectivity cannot be taken for granted in the outdoors—both connectivity to global networks and connectivity to nearby devices. Connectivity to global networks has a significant impact on the outdoor experience. Walking through the woods while connected to a mobile data network with emergency help just tap away is different than walking through the woods while completely disconnected from outside networks.

Today, computers are highly modular in that they are coupled with a wide variety of sensors and network capabilities, appearing in many forms to address different needs. For example, a smartphone contains many sensors like GPS, accelerometer, gyroscope, biometric, ambient light, camera, microphone, and more; and usually includes both Wi-Fi and cellular communicators. And smartphones almost always have a small form factor that is comfortable to hold in one's hands.

In considering different roles for computing technology, this book examines an array of theorized, designed, and prototyped systems. Widely available handheld devices facilitate group tasks, as featured in the science-focused chapter by **Polys** and his colleagues, while the chapter by **Kiefer** looks at the design of augmented reality displays that track gaze. **Bartolome** focuses on a single app, Twitter, mainly used on mobile devices, while Dix explores how an array of apps on different devices collectively can gather information that can combine to reveal insights. Several chapters speculate on emerging and future tech use, such as **Anderson's** reimagining of body area networks for recreational hiking, **Kotut's** exploration of possible tech support for communities that exist on and around the trail, and **Cheverst's** examination of how technologies in mountaineering could enhance and eventually go beyond human mastery over nature. The chapter led by **Quitmeyer** pushes the boundaries of possible tech outdoor experiences by developing prototype tech devices that integrate with nature. **B. Jones'** chapter on wilderness search and rescue involves portable devices carried by team members and a desktop physical system with projected images at the command center in a parking lot, for which each device contributes to different levels of situational awareness. **Alsaleem's** tetraski is a kind of distributed system with physical input devices that are carried by both the tethered skier and the skier using the tetraski. The tethered skier's controller is a handheld device and the skier's controller is either a sip-puff tube or a joystick.

2.4 Interactions

The study of interaction in HCI examines the ways that humans and computers connect through the use of technology. In its earliest days, humans would craft

their input to technology on cards or electronic tape or other media, which evolved into a specialized command language. The emergence of HCI as a discipline in the 1970s and 1980s corresponded with a more direct interaction between human and technology, with immediate feedback that led to richer connections and a much larger collection of tasks that could be accomplished. Increasingly thereafter, HCI broadened in its view of interaction, to include ways that technology blends into the tasks that people do in less visible ways.

Evidence-based knowledge can capture the physical and mental capabilities of a typical human-relevant in completing tech-related tasks, as seen in the relationship between distance, size, and time for hitting a target as captured in Fitts's law (Fitts 1954) and in timings for key presses and cognitive determinations in KLM and GOMS (Card et al. 1980). These are reflected in HCI guidance like Shneiderman's rules of thumb that provide interface design advice based on human abilities to recognize, remember, process information (Shneiderman et al. 2016), and Dix's long-term memory networks and scripts that provide ways to represent knowledge connections that people form during decision-making (Dix et al. 2003).

Definitions and categorizations of interaction seek to differentiate ways that humans engage with their use of technology. For example, Preece, Rogers, and Sharp categorize interaction into five types: instructing, conversing, manipulating, exploring, and responding. Each type captures a different style, whether a command to accomplish a task or a dialogue between the human and computer or the exploration of a virtual space (Preece et al. 2019). Only one of the types—responding, a recent addition to a newer version of the textbook—is initiated by the technology to represent the tech-driven notifications and interruptions that often result from sensed information. Increasingly, it has proven important to consider not only direct, user-initiated interaction but also indirect interactions driven by sensors, cameras, biometric devices, geopositioning systems, and more. Numerous recent papers describe the notion of a third paradigm (Harrison et al. 2007) and a reconceptualization of interaction (Sellen et al. 2009) that encouraged researchers and practitioners to look beyond a human–machine coupling to consider the rich challenges and opportunities in the field of HCI through the notion of embodiment, focused on tight interconnections between humans, technology, and the places and situations in which interaction occurs through learning, speech, and gestures.

This expanding view of interaction melds with the vision of this book for HCI outdoors, reflected by the many chapters that feature interaction that goes beyond traditional interaction. For example, the chapter of **Fails and M. Jones** examines how technology augments outdoor experiences for children, keeping them safer and more informed. Several chapters examine emerging or understudied technologies, e.g., **Patrick** and his colleagues explore how emerging bone conduction devices can support multiple audio channels in noisy outdoor settings, while interactions in **Al Saleem's** chapter take place on the ski slope via the "sip and puff" input devices used by paraplegics. In their chapter, **Aguiar and Green** explore how a digital object can transform the way interpersonal interactions take place in an outdoor space. These and other chapters demonstrate the nontraditional ways that people interact

with technology, and, in particular, the unique challenges that arise in settings when technology could prove annoying or even dangerous if designed poorly.

Bringing together the three pillars of HCI, it is important to consider humans and their challenges and opportunities in outdoor settings to understand how they want and need to interact with technology—or perhaps why they want to keep the technology in the background—to appropriately enrich their experience. Table 1 provides a roadmap to key factors to consider when exploring HCI situations in the outdoors, and in so doing it highlights avenues for future exploration and application. There is much to be learned in exploring different populations, technologies, and outdoor settings. The next section describes the evolution of the HCI outdoors research area, setting the stage for a description of the book chapters in the final section of this chapter.

3 The Emergence of HCI Outdoors

This section seeks to set the context for HCI outdoors by reviewing milestones in its emergence as an area of interest for researchers and practitioners, starting with some of the inspirational foundations from the 1990s and early 2000s, and then interconnecting and evolving through events and workshops in the 2010s. This book emerged as a core output from several of these workshops, collecting current work on HCI outdoors from participants in one or more of the workshops.

The early stages of the study of HCI explored people's interactions with computers in highly controlled indoor settings, but in 1991 Mark Weiser put forth a new vision of computing that he called "calm computing." In the last paragraph of "The Computer for the 21st Century" (Weiser 1991), Weiser wrote this about the potential of calm computing:

> There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods. [emphasis added]

Weiser seemed to be comparing his new vision for computing with a computer-free outdoor experience, with the assumption that "taking a walk in the woods" did not involve a computer and somehow was better for it. In the years since Weiser's vision was put forth, advances in computing technology have made it common to bring, or have available, highly connected computing devices when taking a walk in the woods. Because of this, Weiser's comment is even more apt. Researchers and practitioners in HCI must carefully consider whether a walk in the woods with a computer is as refreshing as a walk in the woods without a computer, or indeed whether that should even be a goal in pursuing HCI outdoors.

In a 2014 article in interactions magazine, Richard Coyne reflected on the merger of smartphones and nature outdoors (Coyne 2014). In the article, Coyne first lays out the case for nature as a restorative environment and then reviews potential pitfalls

of bringing ubiquitous computing (which is not always calm computing) into that environment. But his point is not to leave the computing technology indoors, at home, while one is out in nature. Instead, he argues that smartphones and apps, "like a stunning new artwork," can "disrupt, and therefore reveal, aspects of our experience of the natural world." The editors of that issue wrote "we hope his story will lead to discussions about how HCI relates to nature" (Wakkary and Stolterman 2014).

HCI outdoors is not limited to pondering smartphone use in refreshing natural settings. Rogers' "research in the wild" methodology explores ways to take evaluation of interactive systems out of controlled laboratory settings (Rogers and Marshall 2017). A critical part of research in the wild is allowing people to interact with a system in their own environment and on their own terms. Many times, that environment is located outdoors. However, this outdoor setting is not necessarily in the woods or nature. Much of the research in the wild that takes place outdoors has been done on city sidewalks rather than forest paths.

Several workshops have been held to discuss perspectives and work related to HCI in the outdoors. These workshops include the NatureCHI series (Häkkilä et al. 2016, 2017) (as summarized in (Häkkilä et al. 2018)), Tech on the Trail (McCrickard et al. 2018; McCrickard 2017), UbiMount (Daiber et al. 2017; Daiber and Kosmalla 2016) at UbiComp, and an HCI Outdoors workshop (Jones et al. 2018) at CHI. Workshop attendees identified, discussed, and documented core HCI outdoors themes as they relate to many kinds of people, systems, interaction types, and outdoor settings. The editors of this book also participated in organizing some of these workshops. Early versions of many chapters appeared as position papers in the HCI outdoors workshop, and several workshop organizers and participants contributed chapters to this book.

The purpose of this book is to organize current theories, models, and systems related to HCI outdoors. By doing so, we hope to create a convenient place to find a wide range of current work and to accelerate progress in understanding HCI outdoors.

4 Overview of This Book

The 18 chapters in this book are organized into 5 parts, with each part representing a theme that the editors identified in prior literature or that emerged from outdoors-focused HCI workshops and other events. This section describes each of the parts and provides a brief overview of the chapters.

Part I: Rural Contexts The rural context is different from the urban context for which many interactive technologies were developed. These differences include differences in culture and infrastructure. The two chapters in this section reframe the rural from a pastoral fantasy where city dwellers go on vacation to a rural realism where people live. In the language of an American folk song, "the summer folks call it Paradise Mountain but we call it Poverty Hill" (The Kingston Trio 1964). The reality of rural life presents a unique set of opportunities and challenges for HCI outdoors that remain largely unexplored.

Dix uses a walk around Wales as a genesis for scholarship to reflect on interactive computing at the physical margins of Wales as well as the social and economic margins of society as seen in remote rural communities. Dix' walk raises questions about the role of the digital revolution in deepening social and economic divides between people at the margins.

Su's chapter explores infrastructure resources and social norms grounded in his experience in the rural West and Midwest of the United States. This chapter is written in an ethnographic style that "leaves the work open to new connections" and invites the reader to actively participate in finding meaning rather than presenting a pre-packaged set of themes and design implications.

Part II: Willed and the Wild The origin of the English word wilderness suggests that it is the place where wild things are located. In this context, the wild things are things that are "willed" in the sense that they act according to their own will rather than being controlled or domesticated by humans (Nash 2014). The wild side of HCI outdoors happens not just in primitive wilderness but also in urban settings—where study participants and other stakeholders act according to their own will, rather than being controlled or directed by a researcher. Chapters in Part II explore different perspectives of different types of research in wild settings.

Balestrini et al.'s chapter reflects on three case studies involving Rogers' research in the wild methodology in outdoor urban settings. In this methodology, the "wild" is the self-willed interaction of a passer-by with the system. The urban environment presents unique logistical challenges in deploying the system and unique challenges to sustainability in the sense of long-term deployment of a system.

Quitmeyer and Kelly move the creation of interactive media into the wilderness in order to drive the continued maturation of technological devices through exposure to a new environment. In this chapter, research in primitive wilderness involves scientific fieldwork sites as locations for developing new forms of behavioral media in the wild—with the belief that the wild setting will result in a very different design than would emerge from a controlled and domesticated setting. A unique feature of this chapter is that it involves tropical climates rather than continental or temperate climates found in many other chapters in this book.

Polys et al. describe a citizen-science application for use in wild forests in the Appalachian region of the United States. The application allows forest farmers to collect information about where forest and medicinal plants grow. That information can be used to manage plant resources in the wilderness without destroying the very characteristics that define the wilderness setting. The application was evaluated in the wild in two senses: first, it was used in wilderness forest areas and, second, users could use the system, however, they wanted. This chapter confronts not only logistical issues encountered when using mobile apps in primitive wilderness areas, but also encounters unique privacy issues related to tracking valuable plants on public land.

Part III: Groups and Communities Chapters in this section explore ways that technology can assist a collection of people toward a common goal or help them to feel more connected. In these chapters, the group might be a single family or an entire community of users. Each group and community brings a different set of goals and expectations to HCI outdoors.

The first chapter in this section is by Kotut and her colleagues, stemming from a series of workshop activities that leveraged expert knowledge to understand who is on outdoor trail settings. The activities sought to identify the people who used trails—whether for work, enjoyment, a sense of accomplishment, or something else—and then to cluster the people toward understanding the axes that define the trail users and the similarities and conflicts that arise between them.

The Neustaedter et al. chapter explores interactions between family members who wish to share an outdoor experience, but with one member unable to join in person. The shared experience is created by mobile phones that stream video and audio during bicycling and geocaching experiences, with the goal of providing a sense of presence and connectedness in the individual who was unable to attend. The authors crafted and deployed a prototype system, reporting on reactions on the quality of the experience and concerns regarding privacy.

B. Jones leads a chapter that examines how technology can assist in search and rescue situations in wilderness areas that lack networking, radio, and other tech-related support structures. The authors explore different roles, including victim, manager, field team, and management team, seeking to understand and support the needs and challenges of group communication. The authors note that technology can be invaluable at times, but it also must balance the desire for raised awareness with the need to complete a portion of the search task without interruption.

Part IV: Design for Outdoors Moving interaction to the outdoors creates a new set of design challenges and opportunities. Chapters in this section raise important questions about interaction outdoors and present design sensitivities or guidelines to consider when designing for outdoor use. Several forms of interaction are considered ranging from one person using a smartphone to several people interacting around a large installed structure.

Cheverst et al. reflect on design sensitivities suggested by different forms of "mastery over nature" that can be supported by technology in the context of mountaineering. This chapter discusses the social context of technology in mountaineering where the community's acceptance of a new technology can evolve over time and often involves nuanced rules. The chapter suggests ways that design of HCI for the outdoors might move beyond the trope of "mastery" over nature.

Fails and M. Jones explore the design of outdoor technologies for children. This chapter begins with the premise that children have different needs and goals than adults. Because of these different needs and goals, Fails and M. Jones present design considerations for outdoor technology for children. These considerations are drawn from the authors' prior work involving interaction design for children and studies of adults' perspective on hiking with children and technology use.

Aguiar and Green present the design of "communIT" a cyber-physical environment that addresses the decline use of public outdoor urban spaces due to an increase in virtual, rather than physical, interaction between people. The cyber-physical environment is a large-scale origami with lighting, displays, and audio that is approximately 9 feet long and 4.5 feet long and intended to increase social interaction in underused public outdoor spaces. This chapter is a focused study of a specific technology for social interaction in urban spaces.

Patrick et al. discuss situational awareness outdoors when using wearable auditory interfaces with a focus on bone conduction head-mounted devices. In the outdoors, traditional wearable auditory interfaces (such as headphones) can prevent people from hearing surrounding activities. These interfaces can be dangerous in some outdoor environments—such as during military operations. Patrick et al. consider how humans can receive auditory signals simultaneously through bone conduction and ear conduction. This chapter foregrounds human perception in the design of technology for outdoors.

Part V: Outdoor Recreation Outdoor recreation involves a person pursuing an activity other than work in the outdoors. The chapters in this section consider several different outdoor recreation activities and consider people with different skills, abilities, and goals. Users bring a unique set of intentions to outdoor recreation. Some intend to have a thrilling adventure; others intend to spend a few minutes at a roadside scenic viewpoint. Technology use during outdoor recreation can support or detract from many of these intentions, and the chapters in this section apply and extend HCI approaches to enable and enrich outdoor recreation experiences. Much work remains to be done to better understand HCI in the context of outdoor recreation.

Hakkilä and Colley describe four case studies involving the design, prototyping, and evaluation in the context of winter sports. They describe unique logistical challenges faced outdoors in the cold such as batteries draining faster and wires becoming brittle. This work involves supporting people who are already engaged in a physically active lifestyle outdoors and who have at least a moderate level of skill. HCI for outdoor winter sports remains largely unexplored, and many opportunities for research exist in this context.

Alsaleem et al. present a field study of a power-assisted ski chair for people with tetraplegia. Alsaleem et al.'s ski chair shares control between the skier and a control partner (ski instructor). More experienced skiers are given more control, while novice skiers are given less. The chapter presents the experiences of eight participants who used the ski chair while downhill skiing. Technology that supports recreation by individuals with tetraplegia, or other disabilities, may increase opportunities for participation for all users.

Anderson and M. Jones present a vision of HCI outdoors in which interactive computing fades into the background while enabling and enhancing a multi-day hike. In this vision, interactive computing is integrated into the equipment, clothing, and practices of a hiker. But computing always remains in the background until it is summoned by the hiker. Computing is meant to support rather than detract from the hiker's intent. Significant design and engineering effort are required to bring this vision to reality. Additionally, more work is needed to understand how interactive computing impacts the restorative nature of outdoor recreation.

Kiefer et al. present a novel approach to modeling gaze-guided narratives for tourists. A gaze-guided narrative is an explanation of a story connected to a specific place. As the tourist moves their gaze, the narrative adjusts the pacing and content of the narrative to dynamically tell a story. This chapter applies a formal modeling approach to specifying and eventually reasoning about a story graph used in a gaze-

guided narrative. Gaze-guided narratives, and tools to support their creation, highlight the dynamic nature of some HCI outdoors activities.

Bartolome presents a study of tweets to investigate the culture of conservation around three-long-distance hiking trails in the United States. Groups of tweets related to each of the long-distance trails were analyzed to find topics, and a classifier was created to find tweets related to depreciative behavior on the trail. Her work suggests that a culture of conservation is not a priority in these communities' conversations on Twitter. While other chapters in this section focus on humans and computers interacting during outdoor recreation, this chapter considers interaction before, after, and during a hike along a trail. This research shows that more work is needed to discuss how HCI impacts and perhaps promotes sound conservation practices.

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Rural Contexts

The Walk Exploring the Technical and Social Margins

Alan Dix

Abstract Walking has long been an instrument of political activism, such as the Jarrow March in Britain and the Salt March in India in the 1930s, and before that of war. It has been a spiritual practice, a source of literary inspiration and in some cases regarded as an art in itself. In the case of psychogeography, the act of walking is an integral part of academic and philosophical practice. However, it is fair to say that walking is not a typical part of HCI research methodology. From mid-April to the end of July 2013, I walked the perimeter of Wales, a distance of 1058 miles (1700 km). This was partly a personal journey encircling the country of my birth, not without overtones of pilgrimage, certainly a symbolic act, and maybe, depending on your definitions, art. It was also a research journey, seeking to understand the social and community issues of the 'margins' (literally and metaphorically) of a modern nation, including the impact or otherwise of information technology. This layering of aims and approaches could be regarded as post-modern, but I preferred the words of the Dean of Cardiff School of Art and Design, who described the methodology as mediaeval, and subsequently the blog about the walk was compared with the writing of Gerald of Wales written in 1188. In this chapter, I explore some of the things I have learnt from this perambulatory research; we will consider the design of mobile technology, the meaning of community and the role of the subjective in academic study. However, the 'results' of this are as much questions as answers. Remote rural communities in Wales, and across the world, often face a deepening of the existing social and economic divides, often fuelled by the digital revolution. Can appropriate design and policy counter the apparently inevitable technological entrenchment of existing power? Methodologically, is there a role for this level of slow-paced physicality and ethically is there a place for physical pain? Finally, a critical aspect of the walk was its permeability. I laid myself open to others as a living lab, and the data gathered was being made available to the entire research community. It started as my journey, but one of the first tangible outcomes was a digital exhibition by others, inspired by, but not 'about', the walk. Just as the act

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of walking collapses the distinction of places into a threaded narrative of journey, is there also a space for research that defies the discretisation of publications as metricised outputs, and dissolves the cabalistic divisions of disciplines and groups, a space for methods of work that link, join and lay themselves open to use by all?

1 Introduction

From mid-April to the end of July 2013, I walked the perimeter of Wales, a distance of 1058 miles (1700 km). This was partly a personal journey encircling the country of my birth, not without overtones of pilgrimage, certainly a symbolic act, and maybe, depending on your definitions, art. It was also a research journey, seeking to understand the social and community issues of the 'margins' (literally and metaphorically) of a modern nation, including the impact or otherwise of information technology.

In this chapter, I explore some of the things I learnt from this perambulatory research. We will consider the design of mobile technology, the meaning of community and the role of the subjective in academic study.

The chapter builds on a number of previous publications about the walk addressing issues from public policy (Morgan et al. 2014) to educational open data (Dix and Ellis 2015) and the nature of walking as a research instrument (Dix 2018b); however, the structure draws most strongly on the APCHI keynote which I gave soon after completing the walk in 2013 (Dix 2013b). Full details of publications and data arising from the walk can be found on the Alan Walks Wales website (Dix 2020).

2 A Brief History of Walking

Being bipedal is one of the defining features of humans compared with other animals, amongst other things giving us the freedom to use our hands to construct (leading to technology) and to gesture (leading to language). Our feet took us out of Africa and across the world from the lush lands of Persia and India to the only recently ice-gripped lands of Britain. For long periods of time, even animal transport was, in the large part, for the transport of goods, and it is only in the modern age that the wheel has superseded the foot for long-distance travel.

So, to a large extent the history of humanity is the history of walking.

2.1 Walking for War

Since the ages of the empires 6000 years ago, walking has been an instrument of war. Europe is crisscrossed by Roman roads built predominantly for the rapid movement of its Legions to control and subjugate an empire thousands of miles from end to

end. This is a useful reminder too, that the technical development of transport is as much to do with the modification of the environment as it is with the development of machines to move through the environment; few cars can travel without roads. Whilst many animals accidentally create paths and tracks worn into the ground, we engineer these paths.

The histories of military campaigns are full of long marches: Napoleon's army lost in the snows of Russia, Mao's Long March. These become the subject of fable and folk tales, reflecting the close connections between narratives and journey that date back to the earliest times. Indeed, it is only in the late twentieth century that mechanical transport has taken over from the March for long-distance troop movements, and even then often to drop troops onto the ground for foot patrols.

2.2 Walking as Political Activism

More recently, as power structures have partially inverted, walking has been an instrument of political activism. At a small scale, the foot demonstration with banners and close-packed marchers is a common sight in modern states, albeit if these are sometimes crushed with more or less violence and sophistication. Protest walks can be used to highlight issues or to disrupt the fast flow of non-pedestrian traffic. In some cases, for example, the 'Marching Season' in Northern Ireland, it fulfils an older purpose of claiming land.

While the majority of walks of political activism are short, long-distance walks, by their rarity and by their scale, have created both immediate impact and a permanent place in the collective history. Notably in the 1930s, at opposite ends of the British Empire, Ghandi's Salt March in India protested against the draconian tax on salt, whilst the Jarrow March from Newcastle to London in the UK highlighted the poverty of the depression in the North of England. In the latter case, the walk was not just for its own impact, but because the walkers could not afford the one pound train fare to London to make their protest there. While the drone or inter-continental missile delivers the message of the powerful, the foot is the weapon of the poor.

2.3 Walking as Pilgrimage

Walking is often deeply connected with spirituality and across the world there are sites of pilgrimage, where it is not just the being at the place that is significant, but also the manner by which you get there. You may fly to Mecca but everyone walks seven times around the Kaaba; in Croagh Patrick in Ireland, climbing barefoot over the rough stones is part of the pilgrimage, bloody feet and all; and when Henry II did penance for the murder of Thomas Becket, he walked in sackcloth and ashes to Canterbury—the King just like a pauper.

2.4 Walking in the Humanities

Walking has also been traditionally associated with the arts and literature. In Australia, the songlines cut across the country, with stories of the dreamtimes attached to places along the way. Taking travel more generally, while the road movie is a recent genre, journey tales stretch back many millennia from the Exodus of the Israelites to Jason and the Argonauts in Greek mythology. In the Outer Hebrides, near the Isle of Tiree where I used to live, there are even special songs for 'waulking' the cloth, in early days literally treading on the wet cloth to set it.

Walking was critical in the European Romantic movement of the nineteenth century. Wordsworth is reputed to have walked 175,000 miles in his lifetime (Macfarlane 2013, p. 16), but also composed much of his poetry whilst pacing his study in Dove Cottage. His sister reported that his study was 12 paces across, and it is perhaps no surprise that his most common verse form was iambic pentameter, five 'iambs' each of two syllables, just like five left–right paces, with an extra pace at the end to breathe and turn—a perfect match between space and metre. Wordsworth was maybe more excessive, but not alone in his commitment to walking, which is a continual theme in nineteenth-century writing; Rouseau said "*my mind only works with my legs*" (Rousseau (1782), quoted as in Macfarlane (2013, p. 27)).

More recently, psychogeography has adopted walking as a major facet of its methodology (Coverley 2010). This often involves deliberately arbitrary paths, for example, drawing a shape on a map and then trying to stick as close to it as possible. The idea here is that this avoids taking the obvious main routes and therefore immerses the walker in areas in a semi-random way, making each stand more starkly due to its unexpected juxtapositions.

The Wales walk is not so arbitrary, taking as route the existing borders and coasts of Wales, and yet there is an element of unchosenness, and there were certain areas, which you are forced to walk through, that you might otherwise avoid.

Psychogeography has been critiqued as being rich in methodology, but poor in results. The early idea was to try to understand the relationships between the physical geography of a neighbourhood or area in relation to its 'feel' and the impact on the psyche of visitor (and possibly inhabitant). Certainly from personal experience, it is challenging to turn the rich experience of the walk into lessons or results that can be useful more generally.

Psychogeography has also been predominantly interested in urban environments, but there are a number of writers, notably MacFarlane in his travel trilogy "The Wild Places", "Mountains of the Mind" and "The Old Ways", which are focused on the countryside and wilderness (Macfarlane 2008, 2010, 2013).

Given all of this, it is worth noting that today the rich walk for exercise or pleasure, and my own walk, albeit unusually long, was freely chosen. However, the vast majority of miles walked are not chosen: the refugee, the homeless, the worker who cannot afford bus fares or the old person in the countryside where there is no transport. Walking can be the weapon of the poor but is more often simply the lot of the poor.

2.5 Walking in HCI

While there was an extensive literature in these other areas, at the time of the walk there was relatively little within the HCI literature itself, the main exception being the use of walking as a means to elicit emotional impact of places (Bidwell and Browning 2006; Stanton Fraser et al. 2013) and the way walking fitted into everyday practices of rural life (Bidwell et al. 2013). However, in the intervening years, work on walking (Eslambolchilar et al. 2016; Posti et al. 2014), running (Curmi et al. 2013; Spillers and Asimakopoulos 2014) and other outdoor activities has grown dramatically as is evidenced by the chapters in this volume and the popularity of a number of workshops including NatureCHI (Häkkilä et al. 2016), CHI Outdoors (Jones et al. 2017), UbiMount (Daiber et al. 2017) and Technology on the Trail (McCrickard et al. 2018; Virginia Tech 2017).

3 Walking Wales

3.1 The Wales Coast Path

In May 2012, the Welsh Coast Path was opened. This is a mapped and way-marked route around the whole coast of Wales, a distance of 870 miles (1400 km). There were existing footpaths around sections of the coast, but this new national coast path linked them together as well as creating many miles of new footpath. This makes it the only country in world with a complete route around its coast. The coastline varies from sharp-edged cliffs to long dune-backed beaches, including some of the most remote rural areas of the country as well as passing through or near all the largest cities and towns. It is hoped that this new path will be a major stimulus to tourism and also be a symbolic part of the campaign to encourage exercise and physical well-being more generally in an increasingly obese nation.

3.2 Borderlands

In addition, there is an existing 180-mile (300 km) long-distance path along the route of Offa's Dyke the 9th Century border between Wales and England. These borderlands have always been contested and fought over leaving the detritus of war: Iron Age hill forts, Roman garrisons, Norman Castles and Offa's Dyke itself. The shifting line cuts north–south, in some places following the meandering edges of the Severn across its fertile flood plains; rather like modern oil-fuelled conflicts, there may have been less fighting if the land had been barren. Even in my own childhood, there were Welsh maps showing 13 counties in Wales and English maps showing 12. It was only during local government re-organisation in the early 1970s that the