Human–Computer–Biosphere Interaction: Beyond Human - Centric Interaction

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Abstract. Current human–computer interaction (HCI) is primarily focused on human-centric interactions. However, people experience many non-human-centric interactions during the course of a day. Interactions with nature, such as experiencing the sounds of birds and trickling water, can reinforce the importance of our relationship with nature. The paper presents the author's vision of Human–Computer–Biosphere Interaction (HCBI) to facilitate non-human-centric interaction with the goal of moving society towards environmental sustainability. HCBI extends HCI from countable people, objects, pets, and plants into an auditory biosphere that is uncountable, complex, and non-linguistic. This paper describes the development and integration of non-human-centric design protocols, requirements, methods, and context evaluation.

Keywords: HCBI (Human Computer Biosphere Interaction), Nature Conservation, Nature Interface, Smart Fashion, Soundscape Visualization, Sustainability, Sustainable Interaction Design.

1 Introduction

At times, human beings seem incapable of mutually beneficial coexistence with nature. The often expressed desire for sustainable relations between man and the environment may sometimes appear to be an unobtainable dream. The problem often seems so intractable that it could appear that the best way to solve all of the world's environmental problems would be to destroy all civilizations. Obviously this is not possible However, it is possible to ask whether humans and nature can be integrated more effectively and mutually in a beneficial manner. The current information technology is capable of providing people with the perception of being close to nature and can be used to promote conservation. However, even though conservation specialists have been actively advocating environmental protection by publicizing current critical situations and by trying to reach the public through state-of-the-art information technologies, such as high-resolution images and bio-acoustical recordings, such efforts can never be more than human–computer interactions, and as such, do not satisfy people's spiritual and psychological need to establish an intimate relationship with the natural world. These efforts are also not sufficient to protect endangered populations [6].

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The missing factor is not knowledge or technology, it is an interface by which interaction with remote animals and the environment can be facilitated, without actual physical interaction, in a manner analogous to people's interactions with their family members at home. It is from this perspective that we introduce Human–Computer–Biosphere Interaction (HCBI).This paper presents our vision of HCBI by offering a conceptual overview, related works, currently developed interfaces, and related discussion. This study is not intended to propose a solution to any one single technological or ecological problem; however, it proposes a new viewpoint of multidisciplinary HCBI-based design and interfaces.

2 Human Biosphere Interaction

In ancient times, interactions between human societies and nature were significantly different than they are now for both technological and cultural reasons. Technological advances have allowed humans to alter ecosystems significantly. For example, heavy construction equipment can completely denude forest areas to provide sites for mining operations. Such equipment is also used to prepare sites for putatively "environment friendly" residential developments. In ancient times, humans were less capable of altering natural environments and were more spiritually and emotionally connected to nature. For example, during seasonal festivals, Japanese farmers prayed to various gods, thought to dwell in mountainous regions, for favorable weather conditions, and the general population was taught to respect the gods. In this cultural environment, wild animals and their habitats were left undisturbed. Japan's history and culture largely evolved because of benevolent interaction with nature. Although humans suffered from natural disasters, human society inflicted little damage on the natural environment.

Society and even business activities paid respect to the traditional cultural relationship with the nature until urbanization became increasingly widespread. Urbanization has occurred throughout the world. The majority of all western countries are predominantly urban. With the advent of urbanization, human society created a paradox in its relationship with nature. Assuming that a culturally rooted respect for nature endures, do we truly believe we are protecting the natural environment when we damage forested mountain areas to create "ecologically-friendly" residential areas? If humanity desires to live in ecological harmony with nature, why is it necessary to significantly alter mountain terrain and destroy forests? Very few humans now believe in the existence of gods that control weather or other agricultural conditions. We no longer imagine that wilderness areas are occupied by mythological creatures. However, because we no longer embrace the presence of such historical and cultural metaphors in our daily lives, especially in city life, there has been little outcry at the severe devastation of nature brought about by urbanization. Furthermore, the increased availability of information on delicate natural habitats has ironically increased tourism to such areas, resulting in accelerated environmental destruction [6].

Fig. 1. "Roadkill." An Iriomote cat has been struck and killed by an eco-tourist's vehicle. (Photo by Ministry of the Environment, Government of Japan.)

The situation with the Iriomote cat is a good example of how information provided to raise understanding of environmental issues has had a negative impact. As pictured in Figure 1, the Iriomote cat (Felis iriomotensis) is a wild feline, approximately the size of a domestic house cat, found solely on Iriomote, an island in the southern Ryukyu Islands, Okinawa Prefecture, Japan The species was discovered by Dr. Imaizumi in 1967 [17]. However, once information about this new species was widely disseminated, the cat gained significant economic value. A great number of eco-tourists have visited the island, which has been designated as a world heritage area, in hopes of seeing the endangered cat in the wild before it becomes extinct. Consequently, the most significant threat to that species is the possibility of being killed by a vehicle driven by eco-tourists. As the number of eco-tourists increases, so does the number of cars rented and cats killed. Perplexingly, since the news media first reported this ironic fact, there have been even more visits by eco-tourists and even more road kills. It is ironic that the vehicles driven by nature-loving tourists are a significant threat to an endangered species and could result in extinction.The situation is particularly serious, given that less than 100 members of the species are thought to exist.

If information technology could be used to provide a simulated experience of being close to nature and simultaneously promote the necessity of nature conservation, the number of road kills of the endangered species in this world heritage area might decrease. Even though conservation scientists have actively advocated environmental protection by providing information on current critical situations and reaching out to the public with state-of-the-art information technologies, a high-resolution picture of an endangered animal killed by a car, such as that shown in Figure 1, can never be more than human–computer interaction (HCI), and thus, will probably be ineffective at preventing further deaths as such information seems to attract more direct human interaction with endangered species.As noted previously, what is required is an interface that would allow people to experience a sense of connection with the nature but at a distance. To protect endangered species and threatened habitat areas, we need a methodology that allows people to experience a deeply satisfying, but remote,

interaction with nature. This is important because the sense of being a part of the nature may contribute to human emotional balance. A reverent attitude towards nature can provide a starting point to a path to mental and physical well-being [14] . This is a fundamental tenet of Japanese Zen Buddhism. When we are emotionally stressed, recalling or experiencing the beauty of nature can help us recover a sense of well-being [14].

3 Goal of Human–Computer–Biosphere Interaction

Human–Computer–Biosphere Interaction (HCBI) attempts to facilitate non-human-centric interaction with nature by integrating computer systems into the global ecosystem. The key HCBI concepts are:

1. **Physical separation:** Current information technologies allow people to communicate over long distances in real time without direct contact between the caller and the receiver.

2. **Information Connectivity:** Current information technologies are capable of conveying not only explicit objects such as text and voice messages, but also nonverbal messages, even though the feelings expressed may often be unclear or open to misinterpretation. Despite limitations, application of new aspects and interfaces are advancing information communication in ways that extend human and biosphere interactions beyond the language barrier for non-human-centric interaction.

3. **Ecological Neutrality:** By combining physical separation and information connectivity, nonverbal information interaction between human beings and the biosphere is possible. These are "virtual" interactions, and their environmental impact never exceeds their virtual impact, which may be effective for nature conservation.

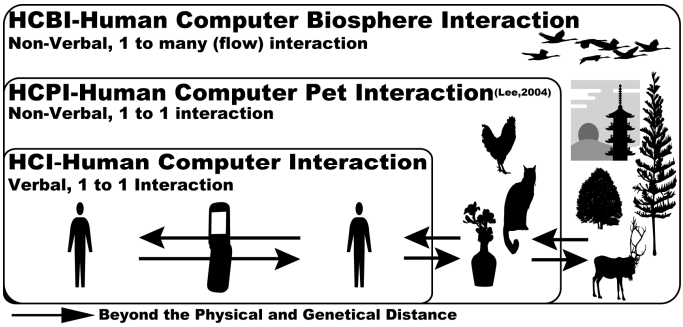

Fig. 2. Human–computer–biosphere interaction (HCBI) concept, an extension of HCI and HCPI. © 2009 [6]

Ultimately, application of these concepts allows us to create virtual impacts on wild animals without ever interacting with them physically. In doing so, we can facilitate interactions among remote animals and the environment in a manner analogous to people's interactions with their family members at home Such interaction could eliminate the need for tourism that results in the death of an endangered species, as mentioned previously. Currently, HCI research and applications, primary focus on human-centric interactions. However, there are many non-human-centric interactions in daily life. Using HCI technology to increase people's awareness of nature and facilitate benign interaction with nature is a key challenge of HCBI.

4 Related Works: Human–Computer Interaction

HCI is a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them [4]. The author proposes to extend HCI and Human–Computer–Pet Interaction (HCPI) to explore HCBI [8]. The conceptual relationships between HCI, HCPI, and HCBI are illustrated in Fig 2. HCI technologies have been employed in a wide range of applications. Computer supported cooperative work uses computer systems to exchange explicit messages to support task-specific activities.

For example, we exchange ideas, thoughts, theories, and messages by encoding and decoding words through computer media, cell phones, email, and chat systems. We also consciously and unconsciously exchange non-verbal cues in our social relationships. This non-verbal information helps us to find an appropriate context during the verbalization process so that the intended message is easily received and understood by the listener. For example, "Tsunagari" communication, a concept developed to foster a sense of closeness between people, allows users to exchange non-verbal cues interactively over a network. The "Family Planter System" is a specific application of Tsunagari communication that was developed for family use [5].Implicit information communication enables non-linguistic and non-verbal interaction among humans and different species, both plants and animals, over physical distances. For example, Lee et al. proposed a novel type of physical interaction and symbiosis

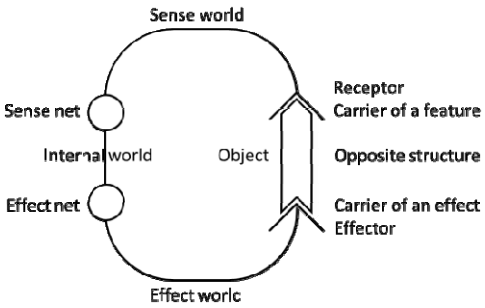

Fig. 3. Functional cycle from von Uexküll's Umwelt theory [15]

between humans and pets using a computer and the Internet [8]. Weilenmann and Juhlin [16] describe how interaction between dogs and humans is affected when new technology, such as a GPS tracking device, is introduced. The dog handler's interpretation of the GPS data supports the hunter's understanding of the dog's intentions.Botanicalls was initially developed by graduate students at New York University's Interactive Telecommunications Program. One of the original goals was to enrich people's relationships with plants and explore the value of nature in increasingly technical environments. The Botanicalls [1] project was included in the Museum of Modern Arts' "Talk to Me" Exhibition that featured projects designed to establish emotional, sensual, or intellectual connections. The Botanicalls system allows plants to phone or tweet when human help is required; for example, when a plant needs water. When people phone a plant they are given the plants' botanical characteristics. Non-human-centric interaction is also reflected in the semiotic theories of Jakob von Uexküll[15]. von Uexküll established the concept of Umwelt, from the German word meaning "environment" or "surrounding world," and suggested that all animals, from the simplest to the most complex, fit into their unique worlds with equal completeness. A simple world corresponds to a simple animal, a well-articulated world to a complex one. Jakob von Uexküll stated that relations between subject and object are the "biological foundations that lie at the very epicenter of the study of both communication and signification in the human and non-human animal" [15]. This relationship is illustrated in the functional cycle diagram presented in Fig 3.

Utilizing HCBI to interconnect the human- and the non-human-centric world can help us increase the physical distance in von Uexküll's functional cycle with ubiquitous computing systems. With HCBI, we can begin to interact with remote subjects beyond normal physical and genetic distances for a simulated direct personal experience of a particular ecology.

5 HCBI Interaction Design

The author proposes a novel cybernetic interface that uses mobile technology to create computer-wildlife bio-acoustical interaction. To establish interaction with wildlife, the monitoring system artificially creates a "prey field" to control the movement of the target wildlife under three conditions: predator-prey relationship, interspecific communication, and interspecific communication in mixed reality, illustrated in Fig 4. As illustrated in Fig 4 (top), bio-acoustical information is one of the signals used by predators to detect prey [13]. In natural environments real frogs respond to the initial call of virtual frogs and begin singing in chorus (Fig 4 middle). The predator detects the emergence of a prey field using acoustic cues from the frog chorus before approaching and entering the prey field to hunt. Bio-acoustical interaction has thus been established. Interspecific communication is considered to be a chorus produced by a group of members of the same species (Fig 4 bottom), analogous to the Internet Control Message Protocol packet Internet groper, or PING, command that is used to determine if a host on a network is reachable from another host [11].

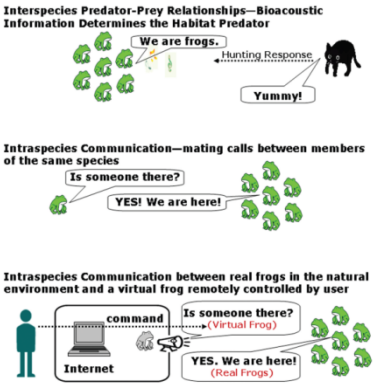

Fig. 4. Interspecies predator-prey relationship (top), intraspecies communication (middle), and intraspecies communication in a mixed reality (bottom). © 2009 [8]

Fig. 5. Wearable Forest [7] @ siggraph'08, 09 Art Gallery

The Wearable Forest [7] uses the HCBI interaction. As shown in Fig 5, Wearable Forest is a garment that bio-acoustically interacts with wildlife in a distant forest through a networked remote-controlled speaker and microphone. It is intended to emulate the unique bio-acoustic beauty of nature by allowing users to experience a distant forest soundscape. This interaction between humans and nature can occur with minimal environmental impact. The Wearable Forest received first place in a juried selection process for the 12th IEEE International Symposium on Wearable Computers, 2008.The Wearable Forest consists of a local audio-visual interactive clothing system and a remote audio I/O system, similar to the Wildlife I/O system, which is placed in a forest. The remote and local systems facilitate intraspecies communication with wildlife in a mixed reality environment, as illustrated in the bottom panel of Fig 4, through a real time bio-acoustic loop. The remote system, consisting of weather-resistant microphones and speakers, was placed in an uninhabited subtropical forest on Iriomote Island.

To interact with wildlife, users can touch the textile sensors, which transfer the user-selected, pre-recorded sounds of wildlife from the garment to the speakers in the forest presents a diagrammatic representation of the system. The bio-acoustic loop, which transfers live sounds bi-directionally from the remote and local sites, gives the user the opportunity to interact with wildlife. For example, in a relatively quiet period after a brief rain shower in the subtropical forest, users in an urban location can play back the croaking of frogs through the remote speaker; in response, actual frogs might start croaking. In this chorus-like mixed reality experience, intraspecies communication between the user and the frogs could potentially give the user a sense of belonging to nature, similar to the peak experience in music therapy [9].

The author and his associates have been operating a networked bio-acoustic streaming and recording system on Iriomote Island since 1997 [6]. Sounds have been continuously streamed in real-time by networked microphones every day, 24 h a day, 365 days a year, for more than 12 years, thus allowing users to listen to live sounds of the ecosystem over the Internet without physically going there. To maintain the remote system, the author enters the tropical forest to replace system components just once a year. Even though the author, in essence, becomes a tourist, the environmental destruction caused by one visit each year is clearly less than 3,000 visitors every day. Having information connectivity with a remote ecosystem can enable control of the extent of the impact resulting from HCBI. By turning off the computer system's power source off, the virtual impact on the remote ecosystem can be removed to maintain ecological neutrality. These are "virtual" interactions, and their environmental impact never exceeds their virtual impact. Inserting electronic technology into natural areas is moderately eco-friendly. While it is not the best solution, it is a better solution than the alternatives.

6 Discussions: Ecological Neutrality

Is inserting electronic technology into natural areas "eco-friendly?"

Yes, if done moderately. There is no right or wrong answer, but moderation is the key, just as it is the key to a sustainable society. Any activity, if conducted too often, can be destructive. An example of a behavior that is only eco-friendly in moderation would be ecotourism, which is defined as:

"Responsible travel to natural areas that conserves the environment and improves the well-being of local people." (**The International Ecotourism Society. 1990**)

However, immoderate eco-tourism can be detrimental to the ecology. For example, it is estimated that more than 3,000 eco-tourists visit Iriomote Island every day. These visitors come from urban areas to experience the island's magnificent ecosystem. They walk in the jungles and trample on plants. As mentioned previously, cars rented by eco-tourists accidentally kill members of an endangered species in areas that have been set aside for their protection. Thus, it can be contended that people who visit the island for eco-tourism purposes become "ego-eco-tourists," even if that is not their

intention. Ironically, attracting tourists, which was intended to raise awareness of the need for conservation, has accelerated environmental destruction. No matter how non-intrusive, the presence of eco-tourists can disturbs nature conservation efforts.

7 Contribution to HCI Community

The author and his associates initially introduced the concept of HCBI at HCI venues discussing environmental sustainability in 2009 [6]. The theory, method, and evaluation of human and wildlife interaction were not discussed in detail because the research was not sufficiently well developed. However, the future direction of HCBI has been suggested by several researchers. In 2010, DiSalvo et al. stated [2] that HCBI points out the inherent contradiction in attempting to use technology to create more intimate connections with nature and Pereira et al. cited HCBI as an example of sustainable computing [12]. Giannachi [3] stated that HCBI clothing, for example the Wearable Forest system, facilitates the creation of a human–computer environment that enables new forms of communication.Interestingly, Mancini explored animal–computer interaction that aims to foster the relationship between humans and animals by enabling communication and promoting understanding between them and emphasized that the study of interactions between animals and computing technology has never entered the mainstream of computer science [10]. Mancini also organized CHI 2012 and hosted a Special Interest Group on Animal-Computing Interaction at CHI 2012. As mentioned previously, the missing factors that would facilitate more robust studies of interactions between animals and computing technology are not knowledge or technologies. The missing factor is an interface that can facilitate human interaction with remote animals and the environment in a manner similar to the interactions with pets and their surrounding environment at home.This paper proposed intraspecies communication in a mixed reality to bridge the gap between humans, computers, and animals. The study reviews existing technologies and touches on physical separation, information connectivity, ecological neutrality, and the functional cycle in Umwelt theory. It reflects the author's multi-disciplinary vision of HCBI, which extends HCI from countable people, objects, pets, and plants into the biosphere, which is essentially uncountable, complex, non-linguistic, and non-human-centric, and potentially points the way to a sustainable society.

8 Conclusion

This study presents the author's vision and practice of HCBI to facilitate a sustainable society. HCBI extends the subject of HCI from countable people, objects, pets, and plants into a biosphere that is uncountable, complex, and non-linguistic in non-human centric scape. Utilizing HCBI to interconnect the human and non-human centric world can extend the subject of interaction based on Umwelt's functional cycle with computing systems. Currently, HCI is focusing primarily on human centric interactions in which the author and co-workers expect some perceivable feedback from others as a response to their inputs before they end an interaction. In contrast, in our

daily lives, there are many non-human centric interactions. These include the sounds of birds, insects, swaying leaves, and trickling water in a beautiful forest, all of which can implicitly imprint the beauty of Nature in our minds. The ecological transition of focusing users's attention toward nature in daily lives using human–computer interaction technology is a key challenge of Human–Computer–Biosphere Interaction. This research accomplished to develop and integrate the non-human centric interaction design protocols and methods.

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