Tele Echo Tube: Beyond Cultural and Imaginable Boundaries

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ABSTRACT
Currently, human-computer interaction (HCI) is primarily focused on human-centric interactions; however, people experience many nonhuman-centric interactions during the course of a day. Interactions with nature, such as experiencing the sounds of birds or trickling water, can imprint the beauty of nature in our memories. In this context, this paper presents an interface of such nonhuman interactions to observe people's reaction to the interactions through an imaginable interaction with a mythological creature. Tele Echo Tube (TET) is a speaking tube interface that acoustically interacts with a deep mountain echo through the slightly vibrating lampshade-like interface. TET allows users to interact with the mountain echo in real time through an augmented echo-sounding experience with the vibration over a satellite data network. This novel interactive system can create an imaginable presence of the mythological creature in the undeveloped natural locations beyond our cultural and imaginable boundaries. The results indicate that users take the reflection of the sound as a cue that triggers the nonlinguistic believability in the form of the mythological metaphor of the mountain echo. This echo-like experience of believable interaction in an augmented reality between a human and nature gave the users an imaginable presence of the mountain echo with a high degree of excitement. This paper describes the development and integration of nonhuman-centric design protocols, requirements, methods, and context evaluation.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors.

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Keywords
HCBI (Human-Computer-Biosphere Interaction), Nature Interface, Sustainability, Sustainable Design.

1. INTRODUCTION
Human beings can imagine the mountain echo in a nature environment because our brain has the ability to record and store the creature as a cultural context of a textbook. Since each person's history and experience are different, the imagined presence of a mythological creature differs relative to the size, shape, and type of the cultures, as illustrated in Figure 1. A contemporary approach to observing the presence of "mountain Echo" is to sing out "YO-HOOOOO!" very lively on the mountain site. By listening to the reflection of the sound, we can observe and share the presence of the mythological creature in a cultural way. According to Greek mythology, Echo was the personification of echo.

This study has attempted to understand the processes of nonhuman-centric interaction between users and remote uninhabited environments through the use of information technologies and reveal new knowledge regarding such interactivity by examining the famous mythological phenomenon, "echo-sounding experience." In doing so, this study hopes to discover the cultural cognitive processes of our imagination mechanism. Such a discovery would help us design an interactive system that leverages the boundary of the real and virtual worlds by engaging a cultural cognition to perform a nonhuman-centric interaction with a culturally imaginable creature.

This paper will discuss the design, development, and evaluation of a system to tackle the previously mentioned mythological phenomenon in a contemporary real-world setting. First, on the basis of related studies, the author proposed a new concept for this study and will design a new experimental system based on related studies and methodologies. The method and requirements for developing the experiment system are also described. In addition, the imaginable process of the nonhuman-centric interactions of users is observed in the exhibition setting. Finally,

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on the basis of the observation results, the overall findings are discussed, including an explanation of the mythological phenomenon and possible applications of the system. 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 HCI design and interfaces.

The structure of this paper is as follows. Section 2 details related studies and Section 3 describes the conceptual overview and the requirement of our proposed system. Section 4 describes the system requirement. Section 5 presents the results, and Section 6 discusses the discussion and application in detail. Section 7 summarizes the results, discusses future plans, and offers conclusions.

2. Related Studies

This study is based on the concept of human-computer-biosphere interaction (HCBI) [8], which is illustrated in Figure 2. HCBI is an extension of human-computer interaction (HCI) and human-computer-pet interaction (HCPI) [11]. Computer-supported cooperative work (CSCW) is based on computer-interaction paradigms to support specific activities. For example, we can exchange ideas, thoughts, theories, and messages by encoding them into transferable words, communicating them through computer systems, and then decoding them. However, in our daily lives, we implicitly exchange and share a great deal of additional nonverbal information to maintain our social relationships, such as messages acknowledging the presence and mood of others [6].

2.1 Human-Computer-Pet Interaction

The consideration of implicit (background) information opens up new possibilities for interaction through nonlinguistic, wearable computing devices, and nonverbal remote communication among different species. Wearable computing devices enable us to extend our spatial interactions and develop human-human communication beyond physical distance [16]. HCPI, illustrated in Figure 2, is a type of physical interaction paradigm that proposes the creation of a new form of media embodying symbiosis between humans and pets through Internet-connected computers [11]. "Botanicalls" was developed to provide a new way for plants and people to interact to develop better, longer-lasting relationships that go beyond physical and genetic distance [23]. Thus, computer systems became a medium through which a telepresence can be expressed among different species in the biosphere through nonlinguistic communication that is perceived and understood by individuals, thus violating the rules of linguistic science [20].

2.2 Cultural Interaction

However, no matter how advanced the technologies are, these remain human-centric interactions. We expect others to provide some perceivable feedback in response to our communication before we end an interaction. However, in our daily lives, there are many nonhuman-centric interactions, such as the sounds of singing birds, buzzing insects, swaying leaves, and trickling water in a beautiful forest. These implicitly imprints the beauty of nature in our minds. Recalling the beauty of nature can help us recover a sense of well-being when we are emotionally stressed. The crucial factor here is not the means of conveyance (words or language), but "something" hovering around, or an atmosphere that we cannot exactly identify. This type of interaction is consistent with the teachings of Zen Buddhism. Zen Buddhism originated in China in the 1st century A.D. after exposure to Indian Buddhism and is widely practiced in Japan [19].

Figure 1. "Yamabiko", ECHO in Japanese mythology. Left: "Yamabiko" in a collection of pictures "Hyakkai-Zukan" [18]. Right: The Illustrated Night Parade of A Hundred Demons [21].

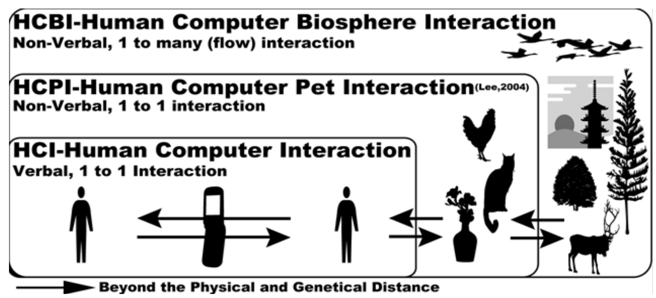

Figure 2. Human-computer-biosphere interaction (HCBI) concept, an extended concept from HCI (Human Computer Interaction) and HCPI (Human Computer Pet Interaction) [8].

2.3 Behavioral Science

The type of nonhuman-centric interaction described in the previous sections is reflected in the semiotic theories of Jakob von Uexküll [22]. Von Uexküll established the theory of Umwelt in Figure 3, from the German word meaning "environment" or "surrounding world." This theory suggests 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, and a well-articulated world corresponds 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 nonhuman) animal" [22].

2.4 Human-Computer-Biosphere Interaction

Kobayashi proposed that, much like elements of the concept of augmented reality, HCBI [8] can be extended to philosophical interactions from countable objects, such as pets and plants in space, to their "surrounding world," which is an uncountable, complex, nonlinguistic "something" that exists beyond our imagination. In the HCBI framework, the sounds of a forest or other natural environments are all information cues that help us to observe reality and build knowledge of reality. Thus, through HCBI, we can experience the marvel of all living beings and their relationships, including their interactions with elements of their reality. With HCBI, we can begin to interact with commonly inaccessible ecological systems.

2.5 Previous Studies

Development in three stages has been ongoing since year 1997. The first development stage was to build a networked Bio-acoustic Streaming and Recording System in the northern part of Iriomote Island (24°20'N, 123°55'E) in the southern Ryukyu Islands, Japan. The real-time streaming system has been upgraded several times over the years to improve long-term stability under unmanned operating conditions. This project received a Jury Recommended award at the Japan Media Arts Festival in 2002. Since 1997, real-time environmental sounds from Iriomote Island's subtropical forests have been monitored by networked microphones and transmitted via the website as "Live Sound from Iriomote Island" 24 hours a day, 365 days a year [8]. The technology behind this networked bio-acoustic streaming and recording system is also used for "AQUASCAPE: the stethoscope for the Earth's waters" through which Internet users are able to listen to sounds in real time, for example: the moving water of a pond in Tokyo, living creatures in a Japanese garden in Kyoto, and a street in Mumbai City, India [8].

The second development stage was in the first version of TET (island version) and was also installed in the northern part of Iriomote Island (24°20'N, 123°55'E) in the southern Ryukyu Islands, Japan. Based on the result of the first version the author developed a Wearable Forest system by which users are able to feel a sense of belonging to a subtropical forest on Iriomote Island, Japan from Los Angeles, USA, Vancouver, Canada and Mexico City[8], Mexico over 10,000 km distance away in real time.

The authors propose TET (mountain version), which extends the subject of interaction from countable objects, pets, and plants to their surrounding environment, which is an uncountable, complex, nonlinguistic, "something" surroundings, much like mythological elements in the Japanese case. This system, TET (mountain version), presents the possibility of more spatial interaction: remote interaction with a mountain echo located 1,200 m above sea level through a communication satellite at 36,000 km above sea level as a global-scale HCI with a cultural empasis.

2.6 Concept Overview

Tele Echo Tube (TET), shown in Figure 4, is a speaking tube that acoustically interacts with a deep mountain echo through the slightly vibrating lampshade-like interface. It is based on the previously mentioned HCBI concept [8], which is an extension of human-computer interaction (HCI) and human-computer-pet interaction (HCPI) [11]. TET allows users to interact with the mountain echo in real time through an augmented echo-sounding experience with the vibration over the satellite network, experiencing a distant mountain forest soundscape in immersive and ambient ways even in the midst of a modern city as shown in Figure 4.

2.7 Mountain Echo

Natural communities contain a spectrum of life forms that interact with each other. Many scientists agree with the judgment that the essence of ecology is the study of interactions among species in their native habitat [17]. In Japanese mythology, it was believed that there are many Yokai (literally demon, spirit, or monster. ECHO, mountain nymph in Greek mythology) living with other animals in the mountain forest environment. Japanese folklorists and historians mention Yokai as "supernatural or

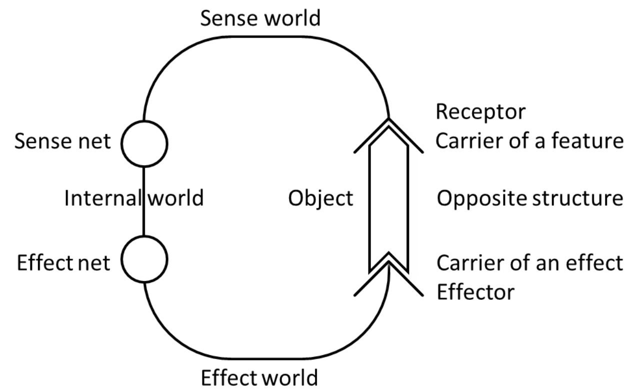

Figure 3. Functional cycle from von Uexküll's Umwelt theory [22].

Figure 4. TET (Island Version) remote system placed in an uninhabited subtropical forest on Iriomote Island, Japan (24°41'90.57"N,123°78'72.47"E)[7].
(note: the chair is not a part of this art work)

unaccountable phenomena to their informants" because Yokai generally have a sort of spiritual or supernatural power. In 1737, Sawaki Suushi, a Japanese artist in Edo Period Japanese, published a picture of a monster called "Yamabiko" in a collection of pictures, "Hyakkai-Zukan" [18], as shown in Figure 1. This is a well-known Yokai who creates a mountain echo. Based on this cultural and imaginable metaphor, TET creates cultural collaboration with "Yamabiko" and provides an echo-sounding experience for users in an imaginable way. TET aims to increase the mythological awareness in a traditional Japanese way through human-computer interaction .

2.8 System Requirement

The study was conducted in an uninhabited mountain forest at Chichibu University Forest, The University of Tokyo in Japan (35°56'17.28"N, 138°48'11.04"E, 150 km from Tokyo). Through ubiquitous technologies, it is generally considered that a typical environmental monitoring near urban areas can be performed effectively. However, in those remote areas, such as the home range of "Yamabiko," the availability of electric power and information infrastructures for monitoring wild animals is either limited or nonexistent. This is primarily because the profitability generated by infrastructure-based services is usually low in areas such as the sanctuary forest where the number of users is small in

Figure 5. Furthermore, in areas where no technological infrastructure is present, observation over a long duration (e.g., over several years) is difficult. Thus, it was necessary to develop methods that make TET happen while using the fewest possible resources. The following system specifications were defined for the development of a long-term observation tool.

1. The equipment must be able to operate in an extremely humid and hot subtropical forest environment.
2. The equipment must be highly stable to facilitate long-term unmanned operation.
3. The equipment must be remotely controllable to facilitate recovery from any unexpected system problems.
4. The equipment must facilitate the reduction of field observations and labor costs [15].

3. SYSTEM DESCRIPTION

TET (mountain version) consists of remote, communication, local, and interaction systems. The subsystem consists of the following four components, Remote System, Communication System Local System and Interaction System.

3.1 Remote System

The remote and local systems perform a remote interaction to create an echo-sounding experience with “Yamabiko” (ECHO, mountain nymph in Greek mythology) in Figure 1 through its live sound pipe through the satellite-networked Internet. The environmental sound and video in the mountain forest have been recorded and monitored by a landscape monitoring system since 1995. In addition, the real-time sound and video archives have been broadcast through an Internet website as “Cyber Forest Project,” The University of Tokyo’s Cyber Forest website [1], for every day since 2009. The real-time streaming system has been improved several times to achieve long-period stability under unmanned operating conditions. The remote system, shown on the left in Figure 4, is placed in an uninhabited mountain forest at the Cyber Forest Project site in Figures 5, 6, and 7. Networked microphones and speakers were placed to create the echo-sounding experience for 24 hours over 365 days. The weatherproof microphone consists of a nondirectional microphone wrapped in a sheet of thick waterproof sponge and a plastic hard mesh. The joint part of the microphone and an audio cable connecter are shielded by waterproof putty and tape to protect them from outside moisture. The microphone is tied onto a trunk of a tower in Figure 7. An A/D device converts the analog audio signal of the microphone (speaker) to a digital audio signal, and transfers the signal to an audio processing system with extremely low noises.

3.2 Communication System

The digital signal cable can be extended up to 10 kilometers without any digital distortion. Next, the digital audio signal is connected to the audio processing system. This audio signal is digitally processed to enhance its quality by remotely controlled real-time audio processing software. The processed audio signal is sent to the en-recording system, encoded into an MP3 live stream, and recorded as WAVE sound format files. The MP3 live stream is sent to a stream server at the Date Archive System directly through the Internet. The MP3 live stream is played on various MP3-based audio software at different locations all around the world simultaneously. The storage/analysis system stores WAVE

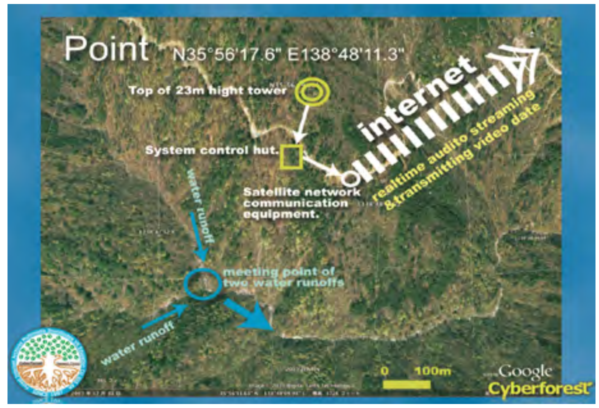

Figure 5. TET (Mountain Version) placed in Cyber Forest project site, located 1,200 m above sea level, The University of Tokyo Forests, Japan (35°56'17.28"N, 138°48'11.04"E).

Figure 6. The home range of “Yamabiko” in Cyber Forest project site.

Figure 7. Audio system, Weatherproof digital camera and solar panels placed in Cyber Forest project site.

Figure 8. Data Communication System: Satellite Internet dish, solar panels, and control house in Cyber Forest project site.

sound format files which are sent from an audio encoding/recording system into its storage system: it is capable of storing audio files which are recorded continuously for several decades. The Data Communication System provides a satellite-based internal computer network in the audio digitizing/streaming/recording system, and also provides Internet access to/from the system. Thus, all systems are remotely controllable through the Internet. Furthermore, a remotely placed monitoring system keeps track of all the system information through SysLog and SNMP software continuously. This management capability allows us to keep monitoring all the system information, from the input level on the microphone to the data traffic delay on the Internet connection over the satellite from the Data Communication System in Figure 8. The system continuously captures and transfers the live soundscape to a local system over the Internet within several seconds.

3.3 Local System

The local speaking tube system consists of networked microphones, speakers with a vibrator, and an echo canceller as described in Figures 9 and 10. An embedded CPU system receives the live soundscape data from the remote mountain via the satellite network, immediately performs echo cancelling on the sound signal, and sends it back to the remote site immediately in Figure 11. TET (mountain version) runs on a full-duplex audio pipe over the Internet and uses an echo-cancelling process for preventing the audio feedback in the loop.

3.4 Interaction System

The songs of small birds, the trickling of a stream, and the sounds of insects moving about in the mountain forest represent the arrival of spring in the mountain area in Figure 6. To interact with "Yamabiko," users can sing out "YO-HOOOOO!" in a very lively from the local speaking tube to the speakers on the mountain on the remote site, as described in Figure 12. The loopback call at the remote host occurs because the playback sound from the speaker is captured and transferred to the user by the remote host with a spontaneous network delay. When the users hear the loopback call, "their voices within the soundscape" from the mountain with the slight vibration from their hands through the interface in Figure 13, they recognize that the initial voices did actually travel through the mountain environment. This echo-sounding loop with the spontaneous network delay, which transfers live sounds bidirectionally from the remote and local sites, creates an echo-sounding effect, and in doing so, gives the user the opportunity to interact with the presence of "a fickle ECHO" on the deep mountain remotely. Those acoustic interactions indicate the nonlinguistic believability in a form of mythological metaphor of the mountain echo.

3.5 Interaction Measurement Design

First, we introduce some notations used in our interaction measurement. In the case of measuring "echo-sounding experience," performance conditions, or in this case, conditions related to transmission, network congestion, effect from temporary blackout and required buffer size in memory stack vary significantly. In situations where multiple units are deployed throughout the Internet from a remote to a local area operated for extended periods, system stability must be carefully controlled.

However, since the careful regulation of numerous units is unfeasible, developing a robust method with commercial products for a long time and continuous operation was considered essential. In this study, the system performance was addressed by measuring

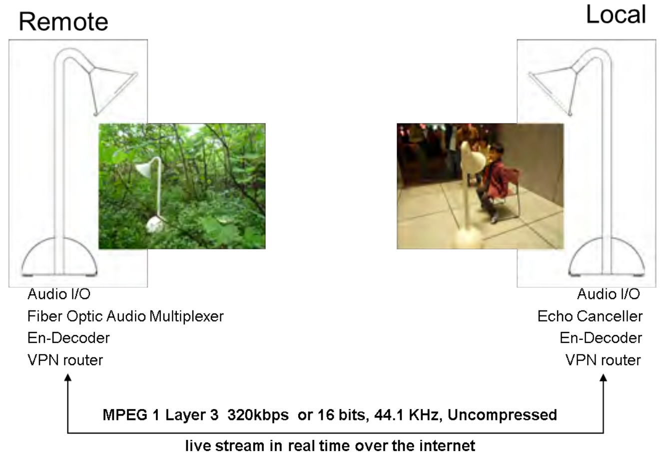

Figure 9. TET (island and mountain version). System diagram of remote and local installation.

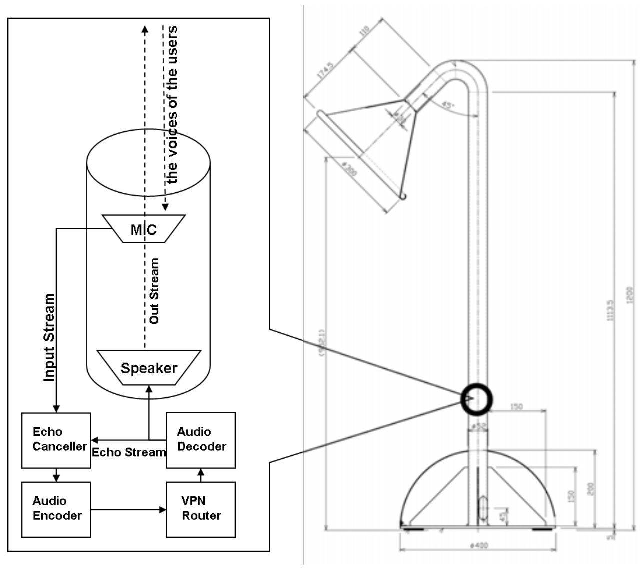

Figure 10. Tube diagram of TET (island and mountain version).

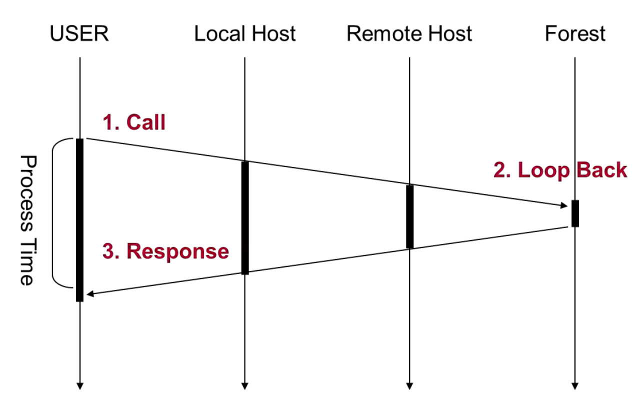

Figure 11. TET (island and mountain version). Diagram of nonverbal interaction between user and echo. This echo-sounding loop with the spontaneous network delay, which transfers live sounds bidirectionally from the remote and local sites, creates an echo-sounding effect.

the cumulative value of the network delay to create the presence of “a fickle ECHO” on the deep mountain remotely. In this study, the system performance was addressed by measuring the cumulative value of the network delay in a user’s input using Equation *(1)* below:

$$T_p = T_c + T_l + T_r \qquad (1)$$

On the Tele Echo System, we have three stages, call, loopback, and response, as shown in Figure 11. T_p means the time of processing for a single echo-sounding experience. T_c means the time of calling process time while the user’s calls travel from the local to the remote site. T_l means the time of calling process time while the user’s call makes a loopback at the remote site in the forest. *True* means the time of responding from the remote to the local site. However, unlike the VoIP application, the MP3 live stream system is designed to transmit live stream data over a robust network with a large-size memory buffer. In addition, a special tuning on the TCP/IP stack to avoid network clipping is essential. Also, we used a commercial off-the-shelf product that can reduce operating cost to demonstrate the validity and usefulness of the time system.

3.6 System Configuration

System conditions fluctuate processing time T_p. Subjects were located in an isolated space. Stood or seated in front of the installation, they were faced by the installation in Figures 15 and 16. One speaker and microphone were placed inside the tube as in Figure 10, located 30 cm from the bottom. A single computer provided recording, communicating and processing with CUI-based operation. The setup comprised a Linux PC with 48 Kbps audio interface (EDIROL UA-25). Custom software was written in C++ using the Speex 1.3 set of open-source audio processing library which interfaced to our previously developed real-time sound streaming system from Iriomote island [8] and the Cyber Forest project site. The whole system was confirmed to operate for more than several years. Absolute 0 ms delay through the system was obtained via an analog bypass around the audio interface. Each trial with reaction from users was recorded as a movie. One of us (H.K.) listened to and watched all recorded digital files and calculated the processing time and observed the facial reactions of all users. To measure the interaction, we used a stopwatch to measure the amount of time elapsed from calling time to response time.

3.7 Trials

The Tele Echo Tube (island version) was selected to be included in the Artech Exhibition of International Conference on ASIAGRAPH 2008 at the National Museum of Emerging Science and Innovation, Tokyo, Japan. The Tele Echo Tube (mountain version) was selected to be included in the BASAL Exhibition, 2010, at the Museo Universitario de Arte Contemporáneo, Mexico. The processing time T_p. was varied over time and locations. Each subject performed each trial once only. Calling by singing out “YO-HOOOOO!” in each trial was randomly initiated by the subject. The subjects were ordered to wait for the reaction from the echo until the arrival of the response. Overall, one session took about one minute to complete. Subjected actions in the movie were analyzed visually and manually to measure

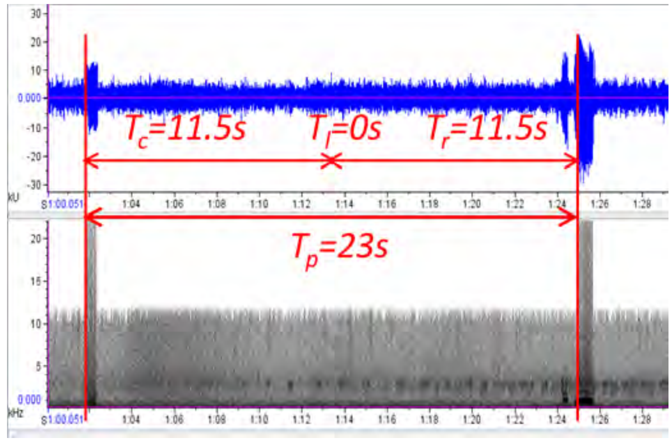

Figure 12. Visualization of echo-sounding interaction on ampitude vs time period (top) frequency vs time period (bottom).

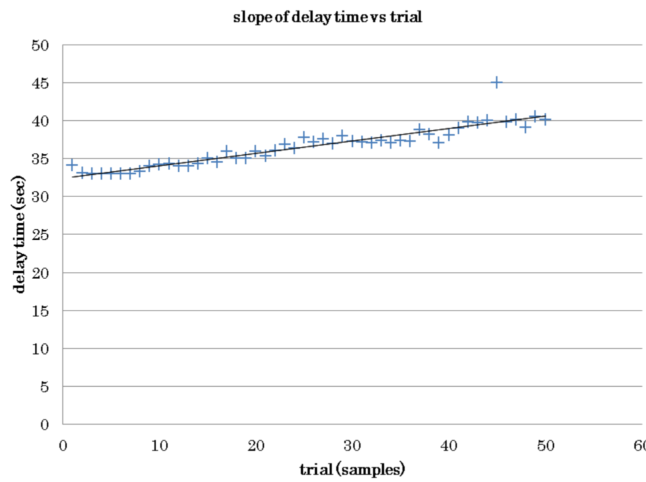

Figure 13. Change in time of echo-sounding interaction with a fickle ECHO over the robust network. Starting processing time T_p = 33 sec, ending processing time T_p = 40.1 sec.

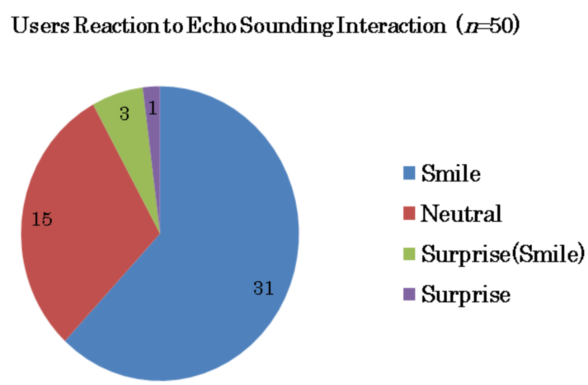

Figure 14. Users reaction to echo-sounding interaction in TET (island version) Artech Exhibition of International Conference on ASIAGRAPH 2008 at the National Museum of Emerging Science and Innovation, Tokyo, Japan.

performance time Tp as a summation of calling time T_c, loopback time T_l, *and* response time T_r per trial.

4. Analysis

The audience (n=50) was used as the subject of this experiment. The subject was placed and stood in front of the installation and change in the echo sounding was observed as a time in equation ***(1)***. Figure 13 shows that the estimated time of echo sounding was measured by the stopwatch when the subjects experienced and performed the integration. The figure result suggests that a change of time in echo sounding was detected in time and the cumulation of the changes caused by the network delay indicated the spontaneousness of the network delay. A comparison of the initial trial (T_p*=33sec*) and the last trial when the trial was ended (T_p*=40sec*) clearly reveals that the fickleness of the mountain echo had changed. Figure 14 shows a change in facial expression during the experiment. Thirty-one individuals out of 50 changed to a smile. One individual out of 50 returned a visible surprise on their face. Three individuals out of 50 returned visible surprise to smile on their faces. Fifteen individuals out of 50 returned a neutral expression on their faces.

5. Discussions

The results from this study can play an important role in the field of HCI by creating a new kind of interaction among humans, computers, and the biosphere beyond cultural and imaginable boundaries. There are a variety of applications that can be advanced through research by applying this information.

5.1 Technical Problems

Maintaining the system with high-quality streaming sound in operation for 24 hours over 365 days requires advanced computer engineering knowledge. The quality of the digital signal processed by the real-time audio processing software decreases as the recording systeuns for a longer period. In most of the cases, the processed signal contains many “clipping” sounds. The “clipping” sounds are caused by slowing down the computation power of a CPU (Central Processing Unit) which is located on the motherboard of the recording system.

Generally, the computational power being slowed down is caused by heat and memory leak. The heat is generated by the recording system itself as the recording system runs in an extremely high moisture and temperature environment in the subtropical forest. The memory leak, losing necessary memory blocks for a computational process, occurs on the recording system because the recording system runs for 24 hours over 365 days. Therefore, to solve the heat and memory leak problems, two identical recording systems are necessary which are placed to run separately for 12-hour shifts each. While the first system is in operation, the second system is not in operation. By following this time shift system, the CPU temperature of the two identical systems is decreased and the memory leak problem is solved.

However, this hardware switching mechanism is an extremely difficult function to run under unmanned conditions. To be exact, a detection of a system shutting-down process on one system followed by a system starting-up process on the other system every 12 hours is not easily detected under unmanned conditions. Because this system shutting-down process is not only caused by this 12-hour shift control software but could also be caused by a long-time power cut, software error could occur as well as other hardware problems. Therefore, to operate all the systems for a long period under unmanned conditions, an intelligent

Figure 15. TET (island version). The remote system is placed in an uninhabited subtropical forest on Iriomote Island, Japan (24°41'90.57"N,123°78'72.47"E) [7].
(note: the chair is not a part of this artwork).

Figure 16. TET (mountain version), selected work for the BASAL Exhibition, Museo Universitario de Arte Contemporáneo (MUAC), Mexico, (2010) [10].

autonomous control system is needed. All the systems were improved several times in the last nine years and finally the stability of the systems was gained. The latest software of all the systems has been operating under the unmanned conditions for the last two years, more than 17,520 hours without a single error.

5.2 Connection to the Concept of Umwelt

This echo-like experience of believable interaction in an augmented reality between a human and the mountain echo gave the users the imaginable presence of “Yamabiko” with a high degree of excitement in the country and overseas in Figure 13, in comparison to the previous work. The type of nonhuman-centric interaction described in this paper is reflected in the semiotic theories of Jakob von Uexküll [22]. 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. “Singing voice” corresponds to a single animal and a simple world; “A sign of presence” corresponds to a complex, well-articulated human world. Thus, a user’s reaction to the sounds can be explained by the Umwelt theory. When users listen to live sounds from the invisible world through the Internet, they tend to pay attention to both a simple singing voice and the complex presence in Figure 17, even though no human exists in the forest.

5.3 Beyond Cultural and Imaginable Boundaries

A comparable type of complex presence existed in Japanese culture. For cultural and mythological reasons, in ancient times, interactions between nature and human societies were more balanced than the interactions that characterize modern society. Before human beings became capable of dramatically altering natural landscapes, humanity and nature were physically separated but spiritually and emotionally connected. Although Japanese farmers interacted with nature in their local environment, the mountainous wilderness areas of Japan were considered to be the domain of gods and mythological creatures. Japanese farmers prayed to the gods during seasonal festivals for favorable weather conditions to ensure successful crop production, and the general population was taught to respect the gods that resided in and protected the mountains. Consequently, wild animals and their habitats in the mountains were left undisturbed for the most part, and Japanese culture was characterized by respectful and benevolent interaction between nature and humanity.

5.4 Human-Computer-Biosphere Interaction

The Wearable Forest [9] in Figure 18, which is based on the HCBI hypothesis, uses the results of this study. The Wearable Forest is a garment that bioacoustically interacts with wildlife in a distant forest through a network of remote-controlled speakers and microphones. It is intended to emulate the unique bioacoustic 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. To interact with wildlife, users can touch textile sensors that transfer the user-selected, prerecorded sounds of wildlife from the garment to the speakers in the forest. The bioacoustic loop, which transfers live sounds bidirectionally 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

Figure 17. The nymph Echo in Greek mythology, (painting by Alexandre Cabanel, 1887 [5], A Collection of the Metropolitan Museum of Art, NY,USA.).

Figure 18. Wearable Forest clothing system : Beyond human-computer interaction [9].

forest, users in an urban location can play back the croaking of frogs through the remote speaker; in response, actual frogs might start croaking. If an appropriate sound is played back at an appropriate time, the actual wildlife might respond to the initial call. In this chorus-like experience, intraspecies communication in mixed reality between the user and the frogs could then possibly give the users a sense of belonging to nature in an experience similar to the peak experience in music therapy, which is triggered by choral singing [12].

The Wearable Forest system was exhibited and evaluated over five days during ACM SIGGRAPH 2008 in Los Angeles, USA, and over six days during ACM Multimedia 2008 in Science World British Colombia in Vancouver, Canada. During the first exhibition, the "out of synchronization" problem was confirmed [9]. The visitors were unable to identify a specific sound from other sounds on the audio live feed from the remote forest. This resulted in users' inability to recognize the potential auditory response from the wildlife, even if the response had occurred to the user in the distant forest. Therefore, even if no response is transferred from the wildlife after the loopback call of the initial call, other acoustical activities in the forest can be perceived as believable responses, such as the sounds of birdsong, buzzing insects, gently swaying leaves, and a tree falling. Those sounds indicate the nonlinguistic telepresence of entities in the forest. From a psychological aspect, participants who experienced the Wearable Forest in the ACM Multimedia 2008 art exhibition described "a sense of oneness" with the remote forest. They rated the episode on a number of scales indicating characteristics of transcendence [27], such as sense of union and timelessness. The result indicates that the Wearable Forest HCBI interface is able to create a sense of oneness between human beings and wildlife beyond physical and genetic distance. This type of nonhuman-centric interaction is consistent with the results reported in this paper.

5.5 Animal-Computer Interaction

The author and his associates initially introduced the concept of HCBI at HCI venues focused on environmental sustainability from 2009 [8] [7] [9] [10]. 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. [2] stated 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 [14]. Giannachi [4] stated that HCBI clothing, for example the Wearable Forest system [9], facilitates the creation of a human-computer environment that enables new forms of communication. 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 [13]. Mancini also organized the ACM CHI 2012 and hosted a Special Interest Group on Animal-Computing Interaction at CHI 2012 conference. 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.

Figure 19. Scarecrows' gathering, near Lausanne, Switzerland (Rastplatz Bavois). This photo was taken by User:Gerbil from de.Wikipedia in July 2006 [3].

Before human beings became capable of levelling mountains with heavy construction vehicles, farmers prayed to gods in seasonal festivals with the tools in Figure 19 or the weather conditions needed to ensure successful crop production, and the general population was taught to respect the gods that resided in and protected the mountains in Figures 1 and 17. The sounds of singing birds, buzzing insects, swaying leaves, and trickling water in a mountain forest implicitly imprint the presence of nature in our cultural way. When we are away from the mountains, recalling the memory of a mountain takes us back to the same place. The crucial factor here is not the means of conveyance (words or language), but the "something" that hovers around; an atmosphere that we cannot identify exactly but that lasts beyond cultural and imaginable boundaries with information technology.

6. Conclusions

Recent technological and information advancements, including satellite imaging, have been unable to confirm the presence of mythological creatures in undeveloped natural locations, and very few humans now believe in the existence of the creatures that control the weather or other farming conditions. However, because we no longer embrace the presence of such cultural and imaginable metaphors in our daily lives, especially in city life, there has been little outcry at the severe materialism brought about by the globalization process. Tele Echo Tube (TET) aims to increase the mythological awareness in the midst of a modern city beyond our cultural and imaginable boundaries. It is a speaking tube installation that acoustically interacts with a deep mountain ECHO through a networked remote-controlled speaker and microphone. It allows users to interact with the ECHO in a sanctuary forest in real time through an augmented echo-sounding experience. In doing so, this novel interactive system can create an imaginable presence of the mythological creature in undeveloped natural locations.

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