Cicada Fingerprinting System: From Artificial to Sustainable

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ABSTRACT
Location estimation with artificial infrastructures for mobile computing has been actively studied, but originally, people get a lot of information from nature during a course of a day. Nature including animals and plants supplies various information acoustically and visually. In this context, we present the concept of Cicada Fingerprinting System, which is a future localization scheme that will enable us to make the most of the information from nature. In our system, users collect the chirp of cicadas as acoustic data via smartphone embedded with microphone. Using the chirp of cicadas such as Wi-Fi fingerprinting, we can specify the location of users regardless of the existence of a roof. That is to say, cicada fingerprinting system applies cicada’s instinctive behaviour to a localization. Furthermore, by our system, users are able to feel a sense of belonging to a nature even in urban area, where we spend much time in daily life. This novel system is designed for making general users conscious of presence of nature around.

Categories and Subject Descriptors
J.7 [Computer Applications]: Computers in other systems; H.5.m [Information interfaces and presentation]: Miscellaneous

General Terms
Design; Human Factors

Keywords
HCBI (Human Computer Biosphere Interaction); Nature Interface; Smart Fusion; Sustainability; Localization; Mobile Computing; Ubiquitous

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1. INTRODUCTION
Cicada Fingerprinting System is a future-present archetype in ubiquitous computing that will enable us to make the most of the information from nature for information technology, especially for localization technique. Nature including animals and plants supplies a lot of information acoustically and visually, thus we can utilize the information effectively.

Using the chirp of cicadas as acoustic fingerprinting, we can specify the location of users regardless of the existence of a roof, which blocks radio waves from the GPS satellite. In our system, we apply cicada’s instinctive habit, which is native habitat, to a location estimation. In some countries, such as Japan and Thailand, there are several kinds of cicada, and each kind of cicada has its own charp. Based on the acoustic data of the point via smartphone embedded with microphone, we can estimate user’s location, which is the paradigm of cicada fingerprinting. This cicada fingerprinting system will be a valuable prototype that combines mobile computing system and ecological system.

Our cicada fingerprinting system is based on the concept of Human-Computer-Biosphere Interaction (HCBI)[1]. The primary aim of our research is to apply living things’ instinctive habit to existing information technology. In fact, various living things in nature supply much information acoustically and visually. Using the information effectively, we can facilitate non-human-centric interaction with the goal of moving our society towards environmental sustainability.

In previous study[2], the authors developed a networked bioacoustic streaming and recording system that continuously streamed, in real time, environmental sounds from an area of subtropical forest on Iriomote Island, water-powered musical instruments in a Japanese garden in Kyoto, and a street in Mumbai, India using a series of networked microphones. The technique described in this paper, cicada fingerprinting, presents the possibility to facilitate non-human-centric interaction in urban area, not in a forest and museum. In urban area, there is seemingly few natural environments, but in fact, various animals and plants live in the area. We believe HCBI in urban area is much significant, because we spend much time in daily life.

In this paper, we present our vision of HCBI by introducing the concept, related works, developed advanced systems, and our new system, cicada fingerprinting system. This paper is not only intended to propose a solution to a single problem, rather, propose a new view of HCBI-based designs.
and interfaces to support our future society using a multi-disciplinary approach from the single problem.

2. PRELIMINARIES

In this section, we present the concept of HCBI[1] for creating a relationship with nature. And, we review the missing factor in existing HCBI systems[3].

2.1 Concept of HCBI

Our cicada fingerprinting system is based on the HCBI concept[1], which is an extension of Human-Computer Interaction (HCI) and Human-Computer-Pet Interaction (HCPI)[4]. HCBI is designed to facilitate non-human-centric interaction with the goal of moving society towards environmental sustainability. In the HCBI vision, the sounds in a beautiful forest or other natural environments are integral to helping us feel one with nature. Thus, with HCBI, we listen to and feel the telepresence of the global ecological system, integrating all living beings and their relationships, including their interaction with the elements of the biosphere.

2.2 Extension of HCBI

Existing HCBI systems[3, 5] focused on the interaction over long distances without direct contact. And these prototypes have not focused on the natural environment in urban area, even though human being spends a lot of time in the area. This is because; compared with a forest, there seem to be few natural environments in an urbanized area.

However, HCBI in urban area is crucially important. In fact, even in urbanized area, natural communities contain a spectrum of life forms that interact with each other. Therefore, our cicada fingerprinting system, which is the prototype of HCBI in urban area, will bring us huge benefit.

Moreover, our system has an advantage in that it is easily available, because the system is based on smartphones that have widely spread in our society. Furthermore, our cicada fingerprinting system provides users’ location information as tangible benefits. This is clear improvement over existing HCBI applications[3, 5], because the users could have gained little direct benefits with the exception of emotional and spiritual healing.

3. CICADA FINGERPRINTING

In this section, we present new localization technique using the sound of cicadas, cicada fingerprinting. Using the chirp of cicadas such as Wi-Fi fingerprinting, we can specify the location of users regardless of the existence of a roof, which blocks radio waves from the GPS satellite. Unlike the existing localization techniques based on Wi-Fi[6] and IMES[7], it is not necessary for cicada fingerprinting system to set new infrastructures and hardwares. We show the concept of cicada fingerprinting system in Fig.1. In cicada fingerprinting, we use the information that includes the kinds of cicada and the volume of the chirp sound. In urbanized area, the natural environment is limited, thus native habitat of cicadas is also limited.

For our cicada fingerprinting, we use general users’ smartphones embedded with microphone. Smartphones have become a powerful platform for people-centric sensing, but few researches do deal smartphone as a translation device from nature to us. Smartphone is close to user’s daily life, thus we can easily achieve a feeling of belonging to nature.

The important precondition of cicada fingerprinting system is the ecology of cicadas. The number of cicadas in one summer changes in the insect’s several-year cycle. And, males sing a species-specific mating song. They are singing with short flights from tree to tree in search of receptive females. In the case of Japan and Thailand, there are many different types of cicadas in one city area. Even in the center of Tokyo, we are able to meet the six kinds of cicadas[10]. And, their flight distances is not long[8]. According to K. S. Williams[10], originally, cicada is not flying insects, thus movement over distances of up to 300m has been observed. In addition, the movements of cicadas in urbanized area are strictly limited so as to protect herself from predators.

Moreover, according to M. Gogala[8], the frequency band of the songs of cicadas depends on the species. Therefore, we can recognize the location by hearing the sound of cicadas. And, periodical cicadas in North America cannot change the native habitat[9, 10]. That is to say, we can regard cicadas as fixed wireless transmitter without battery.

In our cicada fingerprinting system, it is not necessary to unique to all places. Existing localization schemes[11] are used in combination with GPS signals. Similarly, cicada fingerprinting system will be also used as complement.

4. CASE STUDY

To show the feasibility of our cicada fingerprinting system, we designed and implemented the sensing application for Android OS and conducted two simple experiments with Android smartphone, Galaxy S3, in the center of Tokyo.

4.1 For Classification of Places

Firstly, we recorded the ambient sounds at four different points, 1, 2, 3, and 4 as shown in Fig.2. These four points are less than 300m away each other. The point 1 is in the park, which is richly endowed with nature, and there was a lot of ‘Platyleura kaempferi’, which is a kind of cicada. In contrast, the point 2 is on the prefectural road with many cars. The point 3 is in the car park in the campus of the University of Tokyo, and there was a great number of ‘Graptopsaltria nigrofuscata’, which is also a kind of cicada. And, the point 4 is also in the University of Tokyo, and ‘Graptopsaltria nigrofuscata’ and ‘Hyalesa maculaticollis’ were chirping together in this area. The instinctive habits apparently depend on the species.

The acoustic data of 3 seconds in each point are Fourier transformed, and the results are shown in Fig.3. The acous-
The acoustic data of the point 2 contains low-frequency components because of the roaring traffic. And, each frequency distribution has a different peak frequency and different number of peaks as shown in Fig. 3. The native habitat of cicadas depends on the species, therefore we can specify the location of users from the chirp of cicadas.

Through the experiment, we verified that cicada fingerprinting system is capable of classifying the location by the ambient acoustic data. By using only cicada fingerprinting system, it is difficult to specify the location with total accuracy, but we can roughly estimate the location of users.

4.2 For Position Correction

In addition to the above experiment, cicada fingerprinting is effective for the position correction. We conducted the additional experiment in the campus of the University of Tokyo as shown in Fig. 4. In this experiment, we recorded the chirp of cicadas at the same time at two points, A and B. The distance between two points is about 12 m, and the map around the places is shown in Fig. 5. In this area, there is various obstacles of GPS signals, such as wall and roof, thus we cannot specify the accurate location from GPS signals.

The acoustic data of 15 seconds in the point A and B is Fourier transformed, and we show these results in Fig. 6 and Fig. 7 respectively. These frequency distributions are much different, even though these two points adjoin each other.

The place of A is closer to roadside trees, which is native habitat of cicadas, than that of B. And, the result of A contains a high-frequency sound more than that of B. That is to say, the acoustic data is markedly different depending on the distance from native habitat of cicadas.

As shown in this experiment, our cicada fingerprinting system can realize the position correction, by the volume and the frequency of the chirp of cicadas.

5. DISCUSSION

Using our scheme, it is possible to get users’ location information without artificial infrastructure in urban area. We do not believe that the information of cicada fingerprinting system should be unique in all places. Existing localization schemes [6, 11] assumed to combine with other localization techniques such as Wi-Fi and GSM. Similarly, our cicada fingerprinting is used with other localization techniques.

As far as we know, cicada fingerprinting is first technique of using the information from living things for localization. Cicada fingerprinting system applies insects’ instinctive habit, which is same as native habitat, to localization. We already receive various gifts from nature, such as natural energy, food, and spiritual healing, but in the area of information technology, there are only few examples that the information from nature is beneficial to us. Using our cicada fingerprinting system, we will get a new understanding of the presence of nature. This new understanding is much important for preparing a sustainable future society.

Cicada as fixed wireless transmitter is one of the sustainable computing examples, because the season of cicada is limited in a year. Actually, even in urban area, we can collect the information from nature throughout the year, as a proverb ‘The constancy of the benefit of the year in their seasons argues a Deity’ goes. The information from nature...
sounds because of the chirp of cicadas[8].

Moreover, our cicada fingerprinting can be used as an educational tool featured during a digitally enhanced field trip in urban area. In Periscope[12], they also designed to be used as an educational tool for children. However, Periscope required new infrastructures in the woodland. Our cicada fingerprinting will provide the opportunity to have contact with nature without new infrastructures. Additionally, cicada fingerprinting system can be used in urban area, thus users are not required to go to the woodland and forest. Furthermore, periodical cicadas in North America would be good educational material. According to L. H. Yang[9], periodical cicadas are their prime-numbered life cycle, such as 13 years and 17 years, and amazing periodic, synchronized appearance. These long life cycles developed as response to predators. For this reason, many people may not be able to contact with these periodical cicadas in childhood. By recording the acoustic data of the chirp of periodical cicadas, as an extension of our cicada fingerprinting system, we can virtually study these periodical cicadas that should not exist every year.

In cicada fingerprinting system, the sensor node is smartphone, which have a communication function, owned by general users. Therefore, by aggregating acoustic data from each user, we can examine the ecology of animals at many points simultaneously, same as participatory sensing. Participatory sensing and mobile sensing has attracted many researchers to various topics as public health, corporate strategy, and traffic monitoring[13]. However, few participatory sensing applications focused on the biological research and investigation.

6. RELATED WORK
There are more ways to get users’ location information than using Wi-Fi fingerprinting[6]. For example, S. P. Tarzia et al.[11] present indoor localization schemes by analyzing ambient sounds in mobile phone. In their schemes, it is possible to estimate user’s logical location, not physical coordinate. Additionally, SoundSense[14] uses spectral features to classify sounds observed on a mobile phone. The goal of SoundSense application is, users’ activity recognition, not users’ location information. In these ways, we have several applications using ambient acoustic data, but as far as we know, cicada fingerprinting is first technique of using living things’ native habitat for localization.

7. CONCLUSION
Currently, localization schemes need dedicated hardwares and infrastructures such as artificial satellite and base station. On the other hand, various living things in nature supply the information acoustically and visually. In our cicada fingerprinting system, we apply insects’ instinctive habit, which is native habitat, to a localization scheme.

Using our cicada fingerprinting system, we can facilitate non-human-centric interaction, which is based on the concept of HCBI. And, unlike existing HCBI systems, cicada fingerprinting focused on the natural environment in urban area, where we spend much time. Cicada fingerprinting system enables us to use HCBI system casually and unconcernedly, because users don’t have to go far away for it.

Since long ago, our lives are supported by nature including animals and plants in terms of food and energy. We believe, for a sustainable future society, we should utilize the information from nature, including the sounds of birds, swaying leaves, and firefly flashing, for information technology.

8. REFERENCES