

Networked Wearable Musical Instruments Will Bring A New Musical Culture

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Abstract

Many people enjoy music daily, but in a very passive way. To more actively enjoy music, some novel musical instruments are necessary. As a candidate for a novel musical instrument, we propose a networked wearable musical instrument. This paper describes the design of the networked musical instrument as well as a prototype system. Furthermore, we demonstrate several possible novel applications of the networked wearable musical instrument. We think that this networked wearable musical instrument will bring us a novel type of musical entertainment and a novel musical culture.

1. Introduction

Human living is filled with music. Many people cannot spend even one day without listening to any piece of music. The way music is listened to has changed from sitting in front of an audio stereo system inside a house to taking a portable stereo set outside of the house. Recently, moreover, music data delivery services using mobile phones have started. People are becoming able to choose favorite pieces and listen to them anytime and anywhere. In this way, the style of how music is enjoyed is seemingly becoming “active.” However, if we think this situation over, it is obvious we are actively carrying out only non-musical activities, e.g., walking, traveling and shopping. We enjoy the music, but only “passively”, i.e., just listening to it, even though we can choose what we want to listen to.

Performing a musical instrument is a typical active

enjoyment of music. However, it is usually hard to always perform music with some traditional musical instruments like a person can almost always listen to music with a portable stereo set. It is cumbersome to always carry the musical instruments. Additionally, the traditional musical instruments sound outside. This causes surrounding people a trouble. Thus, the enjoyment of performing music is restricted very much. We may enjoy performing music everywhere by carrying a small electrical musical instrument with a headphone. However, such an isolated situation spoils another important enjoyment of musical performance, i.e., interaction or “interplay” with other performers. Therefore, for the active enjoyment of music in daily life, novel musical instruments should be designed. We think “wearable musical instruments” are promising candidates for this purpose.

Several wearable musical instruments have been developed, e.g., YAMAHA MIBURI™ and BODYCODER [1], although their use is still restricted to on a stage. The Musical Jacket [2] developed at Media Lab., MIT, achieves true portability. However, the Musical Jacket is developed as a practical sample application of the “washable computing” [3] and we think the viewpoint as a novel musical instrument for daily musical activities is lacking in its design although it is implemented as a daily wear.

In this paper, we first describe a design of a wearable musical instrument that augments our daily musical activities. The most significant feature of this wearable musical instrument is that it is equipped with a wireless network function. This function allows the wearable musical instrument to communicate with other instruments in an ad-hoc manner. Then, we illustrate a prototype

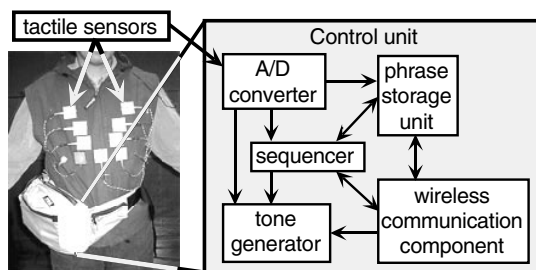


Figure 1. Components of the CosTune

wearable musical instrument. Based on trial experiments using the prototype, we confirmed that a satisfactory session performance is possible with the prototype over an ad-hoc network. Furthermore, we demonstrate several possible novel applications, most of which are achieved by the ad-hoc networking function and show the cultural impact they have.

The rest part of this paper is organized as follows. Section 2 describes the conceptual design of the networked wearable musical instrument. Section 3 describes a prototype system that was developed to evaluate the possibility of a satisfactory session performance with the prototype system. Section 4 demonstrates possible novel applications by the networked wearable musical instrument and shows the cultural impact it can have. Section 5 concludes this paper.

2. The Design

In this section, we describe the design of the entire system. The system consists of “CosTune”s and servers. A “CosTune” is a coined word of “costume” and “tune”. It is a portable musical instrument that can be worn by a user. A server is located somewhere in town and communicates with the CosTunes passing by the server.

2.1. The CosTune

The CosTune consists of a wearable input device and a portable control unit (see Figure 1). The wearable input device is a piece of clothes (e.g., jacket, pants, or gloves) on which a number of tactile sensors that correspond to, for instance, keys of a piano, are mounted. The sensors can be arranged as a user’s like on the cloth. For instance, although nine touch sensors are pasted on a jacket of the prototype jacket-type CosTune (see Fig.5 (d). The white rectangle objects are the touch sensors.), but it is not the only solution. It is allowed for a user to arrange the sensors on, for example, sleeves. However, it must be nonsense to paste 88 sensors on a cloth to allow a similar performance with a piano. We must carefully design how many sensors should be mounted on and how they should be arranged for making the CosTune practical by considering how it is

performed.

By manipulating the sensors, the user can give a musical performance. The portable control unit is equipped with an A/D converter, a tone generator, a wireless communication component, a phrase storage unit, and a sequencer. The output signals from the sensors on the wearable input device are input to the A/D converter, which converts the input analog signals into MIDI (Musical Instrument Digital Interface) data. There are no restrictions of mapping between a sensor and a type of the output MIDI data. A single note can be mapped to a sensor while a sequence of MIDI data can also be mapped to another sensor¹. If a single note is mapped on each sensor, the way of performance with the CosTune becomes similar to a traditional musical instrument. In the meanwhile, if a MIDI data sequence is mapped on each sensor, the way of performance becomes similar to a “DJ” system.

The output MIDI data from the A/D converter and the sequencer, which plays back stored phrases in the phrase storage unit, are input to the tone generator. The output sound signals from the tone generator are input to the headphones. In the meanwhile, if the user wishes, the performed phrases, i.e., the output data from the A/D converter, can be stored in the phrase storage.

The wireless communication component transmits as well as receives “phrase packets” (described in 2.3) to and from other CosTunes and servers. The phrase data as MIDI data obtained from the received phrase packets are also input to the tone generator and, if the user wishes, can be stored in the phrase storage.

2.2. The server

The servers are located at various places in towns like cellular phone base stations. The constituent of a server is almost the same as the portable control unit of a CosTune, but the A/D converter and the tone generator are not necessary (see Figure 2). The role of the server is to store sets of musical phrase data and to exchange them with the CosTunes. Therefore, the phrase storage of the server should be larger and more intelligent than that of the CosTune.

2.3. Phrase packet

The CosTunes and the servers exchange phrase packets. One phrase packet includes the following items:

- Phrase data

¹ If a MIDI data sequence is mapped on a sensor, the sequence is actually output from the sequencer, not from the A/D converter. The output signal from the A/D converter works as a trigger to extract a specific MIDI sequence data from the sequencer.

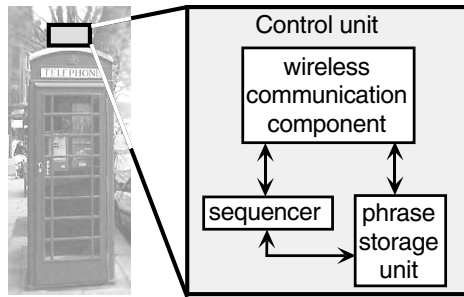


Figure 2. Components of the server

- Length of the phrase data
- Attributes of the phrase data, e.g., rhythm, tempo, timbre, musical genre, a part in the musical structure
- An owner's profile, e.g., owner ID, age, sex, musical preferences, and place of residence.

A phrase is a song component of a certain length, and can be divided in time and/or instrumental type or role. Conversely, a song is defined as an organized set of phrases. Phrase data are sequences of symbols representing notes held by phrases. The MIDI format is usually employed to describe phrase data.

The relations among the musical genre, parts in the musical structure, and timbre should be defined beforehand and shared by all CosTunes and servers. Accordingly, when a CosTune is going to exchange a phrase with another CosTune or with a server, one adequate phrase is chosen according to the relations.

2.4. Requirements of ad hoc networking

The ad hoc networking function is very important for the CosTune system. Figure 3 illustrates an example of an ad hoc network where two network segments already exist, i.e., segment A with four CosTunes and segment B with three CosTunes and a server.

Within a certain segment, all CosTunes and servers must be able to bi-directionally communicate with each other and multicast phrase packets through a shared unique channel. A CosTune user must always be free to join or leave a segment at any time. For example, in Figure 3, a CosTune user has just left segment A while another CosTune user is about to join segment B. In addition, a CosTune should not be involved in multiple segments at the same time. This is because a user usually finds it hard to play and/or to listen to multiple performances simultaneously. Therefore, a segment should be exclusive.

The communication areas of CosTunes and servers should be comparatively small. A 20~30-m-radius area is suitable for a CosTune while a 50~100-m-radius area is suitable for a server. Larger CosTune areas in particular

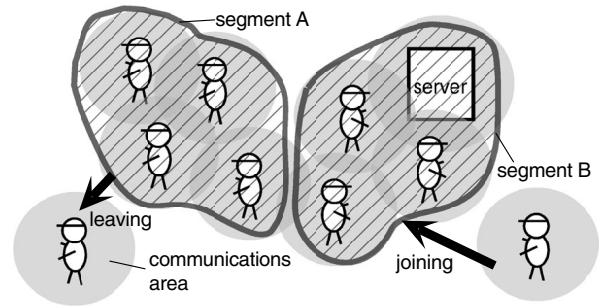


Figure 3. An example of an ad hoc network

make it very difficult to find who the co-players are when the CosTune user has a jam session. Since the users may dance while performing, occlusion-free and non-directional communications is necessary.

2.5. Exchanged data

When a CosTune meets other CosTunes and/or servers, they first establish and/or join an ad-hoc network segment, and then they exchange various data over the ad-hoc network. The types of exchanged data are as follows:

1. User's profile,
2. User's activity mode,
3. Complete song data,
4. Performance data, and
5. Region's profile.

In the rest of this subsection, we briefly describe them.

2.5.1. User's profile. A CosTune user inputs his/her personal data and musical preferences into the CosTune beforehand. The personal data include the user's age, sex, place of residence, and so on. The musical preferences include favorite genres of music, favorite musicians, favorite musical instruments, favorite parts of ensembles, and so on. The user's profile is always open to the public. When a CosTune receives a request message of a user's profile from other CosTunes and/or servers, the CosTune sends back the registered profile data to the requesters. Needless to say, the CosTune user is not required to register items that he/she does not want open to the public: all of the items are optional. However, with more detailed information, the user can enjoy more adaptive, suitable, and interesting services and applications. Affective data can be included as a part of a user's profile data by sensing skin responses, blood volume pulses, and so on [5].

2.5.2. User's activity mode. A CosTune user should tell his/her CosTune what kind of activity he/she wants to do, i.e., activity mode.

- Listening mode
- Private performance mode

- Closed session mode
- Open session mode
- Phrase picking-up mode
- Phrase scattering mode

The CosTune user can choose several favorite modes. The CosTune tells other CosTunes and/or servers from connection requests which modes have been selected.

The details of each activity mode are described in section 4.

2.5.3. Complete song data. A CosTune can download *a priori* given complete song data of certain musical pieces from a server. Conversely, the CosTune user can upload song data that he/she created to a server. Additionally, complete song data can be exchanged among CosTunes. The format of the song data is, for example, the standard MIDI format.

2.5.4. Performance data. While a user performs a musical piece with his/her CosTune, the performance data can be concurrently sent out to other CosTunes and/or servers in realtime. A server also can send out performance data generated by replaying the data of a complete song stored on the server. Performance data are encapsulated in phrase packets as described in section 2.3.

2.5.5. Region's profile. This is provided by the servers. The region's profile informs all CosTune users passing close by a server some features and news of the region where the server is located, e.g., what kinds of shops are numerous, people of what generation mainly gather there, and what kinds of music have recently been performed there. The data may be given by, for example, an administrator in a top-down manner. Otherwise, the data may be constructed based on performance data, user profile data, and so on, collected from those users passing by the server, in a bottom-up manner.

2.6. User support

Performing music with a musical instrument is not usually easy. As for the CosTune, it is probably more difficult to perform it because the performer performs it while doing some other activities. Furthermore, we cannot mount so many sensors on the cloth. Therefore, some functions to support the user should be implemented to alleviate the performance with the CosTune.

A "function-based note mapping method" [4] can be one of the user-support-functions. That is, a specific function of note is always constantly mapped to a certain touch sensor based on the analysis results of a chord progression of a piece of music to be performed. For example, let us assume that a certain sensor is a position

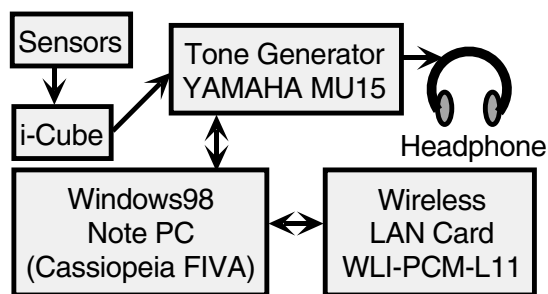


Figure 4. Construction of prototype

for the "third note" which has a function to represent the tonality of the chord. In this case, an E-flat note is mapped to the sensor when the current chord is C-minor, while an A note is mapped there when the current chord is F-major. Thus, a performer can always easily perform the third note only by touching this sensor without considering the chord progression and its analysis results. This function is really helpful to perform, in particular, a jazz improvisation.

3. Prototype system

In order to preliminarily evaluate whether we can actually perform songs while walking and whether we can form sessions with a number of players using a wireless network, we created and tested a prototype system. Figure 4 illustrates the construction of the prototype CosTune. The prototype CosTune is equipped with all of the components described in 2.1. except for the sequencer. We used the i-cube™ system, which is an infusion systems™ product, as the A/D converter. The i-cube system converts input analog signals into MIDI data. On the contrary, the prototype server is equipped with a sequencer.

We prepared three types of interfaces: jacket type, pants type, and glove type (Figure 5). Although any kind of sound can be assigned to any type of interface, we assigned an organ sound, drum sound, and strings sound to the jacket, pants, and glove interfaces, respectively. We applied "function-based note mapping method" to the jacket type prototype. As the wireless communications component, we used wireless LAN cards (IEEE802.11b conformance, 11 Mbps). At present, simply encapsulated MIDI data are transmitted as UDP packets among the CosTunes and the server. "Phrase packets" have not been implemented yet. The transmitting delay is less than 10 ms. This is short enough for most amateur players to play without confusion.

On each CosTune, performance data are converted into MIDI data and are transmitted to the. Then, the server corresponds the received data to a specific timbre based on the MIDI channel (a unique MIDI channel is assigned to each CosTune) and immediately broadcasts the received

data as well as the accompaniment data generated by the sequencer of the server to all CosTunes. Every CosTune receives the broadcasted data and inputs them to the tone generator. Therefore, every player can listen to the performances of all of the players as well as the accompaniment through headphones. If another new CosTune user enters the communication area, the new user becomes able to listen to the other performers' performance. At the same time, the other performers become able to listen to the new user's performance, too.

We demonstrated a prototype system consisting of three CosTunes and one server at ATR exposition 2000 (November 1-2, 2000 in Kyoto, JAPAN) with three players for two days. We were able to comfortably hold session performances with the system while walking. Exposition visitors offered many positive comments, e.g., saying that they wanted it immediately and that it would surely become a business hit. In addition, we let several visitors

try a CosTune, mainly the jacket. They were able to perform quite easily while walking.

4. What CosTune Will Bring

This section describes possible applications that can be achieved by using CosTunes and servers. Beyond a simple extension of either conventional musical instruments or walking stereo sets, CosTune will become a community forming media [6], a direction media for users and cities, and so on. Accordingly, we believe CosTune will bring us a novel musical culture. Each application nearly corresponds to a user's activity mode. Therefore, we demonstrate applications for each mode.

4.1. Listening mode

4.1.1. Networked walking stereo. This mode allows a user



(a) Jacket type CosTune



(b) Pants type CosTune



(c) Glove type CosTune



(d) All components of the jacket type CosTune

Figure 5. Prototype CosTunes

to just listen to a piece of music. Therefore, CosTune is the same as a walking stereo by replaying stored song data by the sequencer and the tone generator. Furthermore, by downloading other song data and replaying them, CosTune can become the same as a portable music data download and replay system using a cellular phone (e.g., “PicWalk” in Japan). If this mode is used together with the phrase picking-up mode described later, the CosTune user can listen to phrases scattered by other CosTunes that the user encounters and/or by the servers that the user passes.

4.2. Private performance mode

4.2.1. Walking musical instruments. By playing music using the wearable input devices, the user can perform his/her favorite music and can listen to it alone. If the user desires, he/she can perform a solo with accompaniment that is performed by the sequencer. The accompaniment data can be easily generated by deleting the parts of the ensemble that the user wants to perform from the song data stored in the phrase storage unit or downloaded from the server. Therefore, the user can listen to music that he/she wants to listen to by creating the music himself/herself.

4.2.2. Personal direction. This mode allows the user not only to privately enjoy musical performances while walking, but also to direct oneself by the performed music. For example, someone who can play a harmonica often perform it on the seashore while watching the sunset. In this case, he/she is directing the situation by adding background music by her/his harmonica performance. It is not so easy to master the free performance of a harmonica. However, this is rather easy to do the same thing by using CosTune because of its supporting functions for novice users. Furthermore, if a server provides some “set menus” of songs registered in the region’s profile depending on the circumstances of the region, the CosTune user can more easily enjoy this self-direction depending on the atmosphere of the place where he/she is. The user can only listen to a priori prepared musical pieces in the listening mode, and can add his/her own performance to a given piece to suit the BGM to his/her feelings much more. This mode relates to the phrase picking-up mode and the phrase scattering mode described later.

4.3. Closed session mode

4.3.1. Augmented street performance. By gathering multiple CosTune performers, and by establishing a closed network segment, the performers can play in concert or have a session performance by fixed performers. The session performance can be listened to by the performers themselves, as well as other CosTune users nearby by

tuning their CosTune units to the session channel. If we prepare a “portable station” equipped with the same components as the CosTune as well as speakers and an audio amplifier, the session performance can be listened to by everybody nearby. Therefore, CosTunes in this mode can be simply applied to an event or a concert.

It may be said that this mode is a mere extension of the conventional street performance. However, we think CosTune can develop a novel style of street performance. For example, a certain style of dance usually has some specific motions and in the motions a dancer touches or hits several specific parts of his/her body. Therefore, by designing the layout of the pads mounted on the different types of clothes while considering dance-style-dependent motions, musical wear specialized to specific dance styles can be created, e.g., a wear for break-dancing. This type of CosTune can enable the performers to concurrently perform music while dancing in the usual manner.

Furthermore, operating the pads mounted on the other performers’ clothes brings another interesting way of performance. This way of performance can be applied to, in particular, an elementary musical education or a cultivation of aesthetic sentiments in a kindergarten. Playing the pads mounted on friends’ backs to perform music is a typical example of this application.

4.4. Open session mode

4.4.1. Ad-hoc session. Different from the closed session mode, everybody can create or join a session anytime with anyone in this mode. This function allows a user to have an ad-hoc session on a street corner with someone who he/she meets for the first time.

This mode is achieved by the following procedure, for instance. A CosTune user wearing CosTune travels about hunting for other CosTune users that want to form or are forming musical sessions in the desired musical genre. When he/she meets (an)other CosTune user(s) at a certain street corner, and when the wireless communication areas of two or more CosTunes are overlapped, the CosTunes first exchange the user profile data. If their musical preferences are similar and all of them are in the open session mode by comparing their profile data, they become “partner candidates.” If the partner candidates are already forming a session, the user listens to the performance, finally decides whether he/she wants to join the session, and then takes part in the session if desired. If the partner candidates have not started a session yet, they negotiate a song to be played together, and newly form a session

If only a small number of players join the session, the sequencer of the CosTunes supplements the lacking parts with minus-N data that is generated based on the phrase data stored in the phrase storage or that is downloaded

from a server.

4.4.2. Musical communityware. This ad-hoc session function enables many unspecific people, who have the same objective, to meet each other. That is, the system can solve the conventional problem of having to find people of similar tastes in order to form a musical session.

There are several systems and projects that allow people to perform remote sessions by exchanging performance data in the MIDI format over the Internet (e.g., TransMIDI [7] and RMCP [8]). CosTune is similar to these attempts in terms of phrase exchange through a network. However, as for musical performances, we regard communications in the real world as important while the communications using the ordinary systems are done in virtual worlds. CosTune allows people to meet in the real world and to have jam sessions in a face-to-face manner: an essential joy of musical performances.

Like this, we aim at supporting the users of CosTune to encounter people who have similar musical tastes as well as to encounter areas that have the users' favorite types of atmosphere. Accordingly, CosTune supports the formation of communities. CosTune in this mode can be regarded as a "communityware" [9] in the real world. Furthermore, since music is a universal language, users can easily communicate with other local CosTune users by taking CosTune abroad and by using it in the open session mode. Namely, CosTune is essentially a borderless communityware.

4.5. Phrase picking-up mode

4.5.1. Musical travel literature. In this mode, a CosTune unit picks up phrases that are scattered by other CosTunes and/or servers. When the CosTune in this mode receives a phrase packet, it checks the attributes of the phrase data and the owner's profile of the phrase, and filters the phrase by comparing it with its user's profile. Therefore, the CosTune automatically collect phrases that are in line with its user's musical preferences while the user is traveling, only if the user in this mode meets other CosTune users in the phrase scattering mode and/or passes by servers.

Accordingly, using this mode, the user's traveling "locus" is recorded as a series of phrases. Therefore, if the CosTune picks up phrase packets reflecting the region's profiles from servers that the user passes, the accumulated phrases in the CosTune can represent the types of atmosphere in the places that the user had visited. Furthermore, from the picked-up phrases provided by the other CosTune users, the CosTune user can recall what kinds of people he/she had met while traveling. Therefore, a basis of "musical travel literature" can be automatically generated. By editing and revising this basis, a more

sophisticated work can be composed. Some automatic composition tools may be applied.

4.5.2. Regional musical culture formation. The servers are basically always in this mode. A server picks up all of the phrases that are scattered by the CosTunes passing by, classifies the phrases based on their attributes and their owners' profiles, and stores them in the phrase storage unit. Therefore, a set of phrases is gradually created in a bottom-up manner.

We are interested in the characteristics of a "specific region" of a city, town, and so on. Specific kinds of people tend to gather in specific kinds of regions. They generate the "atmosphere of the region" and the atmosphere of the region attracts those who like the atmosphere. As a result, regions acquire unique characteristics, e.g., SoHo in N.Y. and Harajuku in Tokyo. We think that the music that is performed in a region must reflect the characteristics of the region. Conversely, the jam session performances and the composed musical pieces must become different depending on the regions where a CosTune user visits. Therefore, we think people who want to enjoy the music of a specific region should actually (not virtually) visit the region and meet people of the region.

Accordingly, people can create a regional musical culture, and the regional musical culture in turn let other people who might be interested in the culture meet there together.

4.6. Phrase scattering mode

4.6.1. Human-mediated musical culture spread. A CosTune in this mode always scatters phrases that are stored in the phrase storage units of the CosTunes around it. The scattered phrases may be picked up by other CosTunes in the picking-up mode and listened to. At the same time, the scattered phrases can be picked up by nearby servers as described above. In this way, phrases can be transmitted by CosTune users moving around. We think it is rather interesting to isolate the servers than to directly connect them via a network. As a result, phrase transportation among the servers can be achieved only when CosTune users move. In other words, the users become the "vectors" of regional music, like butterflies carrying pollen among flowers. Depending on the human flow, the regional musical cultures can be hybridized.

4.6.2. Direction of region. The servers are also basically always in this mode, and scatter phrase packets. The kinds of phrases, i.e., the genre and so on, are not sole but various. The CosTune users passing by the server filter them based on the attributes of the phrases. Therefore, the attributes of the phrases function as communication channels. The

servers should prepare at least two special channels: a top-down regional channel and a bottom-up regional channel.

The top-down regional channel scatters phrase packets that are *a priori* given by the administrator of the server. Using this channel, a “space producer,” for example, can strategically direct the region. On the contrary, the bottom-up regional channel scatters phrase packets that are automatically collected by the picking-up mode. This channel promotes the growth of the regional popular culture.

4.6.3. Dressable music. From another viewpoint, CosTune in this mode is analogous to apparel, adornment, or perfume. A dress has the function of appealing the wearer’s social status, mental situation, daily plans, hobbies, and so on, to those who pass by. For example, a tuxedo lets the surrounding people know that the wearer may be a VIP or that he will take part in a formal party tonight. Additionally, by showing his/her wear to other surrounding people, the wearer puts his/her own mind to the atmosphere brought about by the dress. We think CosTune in this mode has the same effect. By letting other people listen to scattered music, the CosTune user can “dress up with his/her music” to show his/her status, atmosphere, and so on. The self-direction in the private performance mode is closed only for the user himself/herself. However, using the phrase scattering mode, self-assertiveness can be satisfied.

5. Conclusions

In this paper, we first described the design of CosTune, a networked wearable musical instrument. CosTune is equipped with several sensors mounted on clothes as well as ad-hoc networking functions to exchange phrase data and user profile information with other CosTunes and servers located in various places in towns. We also illustrated a prototype system to evaluate whether a session performance can be satisfactorily achieved using CosTunes over a wireless network, and basically confirmed no problems in having a session with the prototype. Furthermore, we demonstrated several possible applications using CosTunes. We believe CosTune will bring novel musical entertainment and a novel musical culture.

Up to now, we have developed a very basic prototype system that is equipped with wearable interfaces and simple wireless networking functions. We plan to implement data exchanging functions to bring the proposed applications to fruition. We are planning to employ a “bluetooth™” chip for ad-hoc networking, and to implement the entire system excluding the clothes with sensors in a cellular phone. Cellular phones are presently

equipped with a bluetooth™ chip, a high-quality sound chip, and the Java virtual machine. Therefore, our goal is to implement everything except for the interfaces and headphones in the cellular phone. By simply connecting a jacket and headphones to the cellular phone, and by downloading the necessary application software as well as the data of a favorite song from the Web, the cellular phone can be quickly transformed into a CosTune.

Acknowledgment

The authors would like to thank Dr. Yasuyoshi Sakai, Chairman of the board of ATR Media Integration & Communications Research Laboratories, for giving us the opportunity to conduct our research. The authors would also like to thank the members of the Advanced System Development Center, YAMAHA Co., Ltd., for their kind support in prototyping the CosTune system.

References

- [1] Bromwich, M. A. and Wilson, J. A.: ‘BODYCODER’: A Sensor Suit and Vocal Performance Mechanism for Real-time Performance, Proc. International Computer Music Conference 1998, pp. 292-295, 1998.
- [2] MIT Media Lab. Musical Jacket Project, <http://www.media.mit.edu/hyperins/levis/>
- [3] Post, E. R. and Orth, M.: Smart Fabric, or Washable Computing, Proc. International Symposium on Wearable Computers, pp. 167-168, 1997.
- [4] Nishimoto, K. and Ooshima, C.: Computer Facilitated Creation in Musical Performance, Proc. SSGRR-2001, L’Aquila, Italy, Aug.6-11, 2001. (to appear)
- [5] Healey, J., Picard, R. and Dabek, F.: New Affect-Perceiving Interface and Its Application to Personalized Music Selection, Proc. the 1998 Workshop on Perceptual User Interfaces, 1998.
- [6] Tada, Y., Nishimoto, K., Maekawa, T., Rouve, R., Mase, K., and Nakatsu, R.: Toward Forming Communities with Wearable Musical Instruments, Proc. International Workshop on Smart Appliances and Wearable Computing (IWSAWC 2001), pp.
- [7] Gang, D., Chockler, G. V., Anker, T. and Kremer, A.: TransMIDI: A System for MIDI Sessions Over the Network Using Transis, Proc. International Computer Music Conference 1997, pp. 283-286, 1997.
- [8] Goto, M., Neyama, R. and Muraoka, Y.: RMCP: Remote Music Control Protocol --- Design and Applications ---, Proc. International Computer Music Conference 1997, pp.446-449, 1997.
- [9] Ishida, T. (Ed.): Community Computing – Collaboration over Global Information Networks, John Wiley & Sons, 1998.