PAPER *Special Section on Artificial Reality and Telexistence*

Tangible Media Control System for Intuitive Interactions with Multimedia Contents

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SUMMARY In this paper, we present the Tangible Media Control System (TMCS), which allows users to manipulate media contents through physical objects in an intuitive way. Currently, most people access digital media contents by exploiting GUI. However, it only provides limited manipulation of the contents. The proposed system, instead of a mouse and a keyboard, adopts two types of tangible objects, i.e. a RFID-enabled object and a tracker-embedded object. The TMCS enables users to easily access and control digital media contents through tangible objects. In addition, it supports an interactive media controller which can be used to synthesize media contents according to users' taste. It also offers personalized contents, which suits users' preferences, by exploiting context such as the users' profile and situational information. Accordingly, the TMCS demonstrates that tangible interfaces with context can provide more effective interfaces to satisfy users' demands. Therefore, the proposed system can be applied to various interactive applications such as multimedia education, entertainment, multimedia editor, etc.

key words: *tangible user interface, context-awareness, interactive media controller, personalized contents*

Introduction

With the rapid development of computing technologies, various media contents (e.g. audio, images, graphics and video, etc) are now available in digital form which can be accessed through computers. With prevalent availability of computers, the use of media contents has also increased. Moreover, these media contents have become one major entertainment tool. Currently, most people use a keyboard and a mouse to access the media contents. However, they still have difficulties with exploiting the contents even though Graphical User Interface (GUI) mitigates the inconveniences of text-based interfaces to some extent. Especially, the elderly, who are not familiar with computers, feel uncomfortable while experiencing digital media contents, i.e. inputting text with a keyboard or selecting an icon with a mouse. Moreover, the GUI is not convenient enough to let the users manipulate the media contents in the space of daily life, such as a living room.

In order to overcome such inconveniences, Tangible User Interface (TUI) has been proposed as a new kind of user interface which allows users to naturally control digital information through physical objects [1], [2]. Ishii *et al.* proposed Tangible Bits, which lets users present and control digital information by exploiting various elements existing in everyday life, such as sound, light, airflow and movement of water, etc [1]. Additionally, MusicBottles and genieBottles use glass bottles as interfaces for playing music or a story [3], [4]. They link media contents to physical glass bottles, and then make users exploit the human sense of touch for interactions with the contents. Musical Trinket provides users with dolls and finger rings to play several music pieces and insert effective sounds [5], [6]. It allows users to synthesize music with their hands. MusiCocktail allows users to blend various kinds of music in the way they mix their beverage [7]. Thus, non-musicians can easily interact with music in a social environment. BlockJam enables users to generate as well as control the digital music contents by assembling blocks or exploiting several buttons on the blocks [8]. Additionally, AudioPad offers a puck, which contains two tags, as the interface for interacting with media contents [9]. These applications provide users with an interactive media player and new kinds of entertainment factors. However, they are limited in achieving users' satisfaction since they offer the same media contents to all users in the same ways without considering their preferences and situational information.

In order to improve the current TUI, we propose TMCS (Tangible Media Control System), which combines the concept of TUI with RFID tags and the tracker [10], [11]. The TMCS allows users to intuitively manipulate media contents by using tangible objects, such as CDs, dolls, etc. In addition, it offers personalized contents according to the implicit context, e.g. a user's profile or situational information using ubi-UCAM (a Unified Context-aware Application Model for ubiquitous computing environments) [12]. The proposed system consists of three key components; tangible objects as interfaces for controlling media contents, context recognizer generating the context [13] from any changes in the environment, and a media controller allowing the user to manipulate the media contents suitable for his or her taste.

The proposed TMCS has following advantages. It provides novice computer users with intuitive interfaces for accessing and controlling digital media contents. In addition, it offers an adequate environment for users' satisfaction by providing personalized contents to the user according to his or her history. Furthermore, it enhances entertainment factors by allowing users to naturally manipulate the media contents, e.g., synthesizing media contents or changing several parameters of the contents, etc. Consequently, the proposed TMCS can be applied to various applications in the

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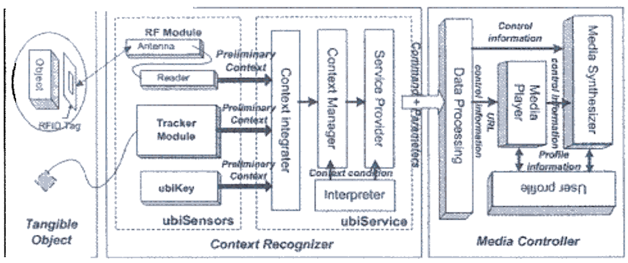


Fig. 1 The architecture of TMCS.

field of interactive training, entertainment, education, media editing, etc.

This paper is organized as follows. In Sects. 2 and 3, we describe components of the proposed TMCS and implementations of the components. In Sect. 4, we quantitatively and qualitatively analyze results of the usability test of the TMCS. Finally, we discuss the conclusion of the implemented TMCS and future works, in Sect. 5.

2. TMCS: Tangible Media Control System

As shown in Fig. 1, the proposed TMCS consists of three key components; tangible objects, context recognizer and media controller. Tangible Objects offer natural interfaces for easily accessing and manipulating digital media contents. Context Recognizer generates contexts of the users and tangible objects. Media Controller allows the users to manipulate multimedia contents according to their preferences.

2. Tangible Objects

Tangible Objects provide users with intuitive interfaces for manipulation of digital media contents. They allow the users to easily access the media contents with the objects. They also offer natural interfaces for synthesizing or inserting the media contents. There are two types of tangible objects, i.e. Media Object and Control Object.

Media Object links a physical object, commonly used in our daily life, to digital information in virtual space. Then, it offers an intuitive interface to users for accessing digital media contents. The object has a stick type of passive RFID tag [14]. As shown in Fig. 2 (a), the embedded RFID tag contains information about media contents linked to the object; it stores an identifier representing the kind of tangible objects, i.e., if the object is a media object or a control object. It also includes information related to the URL of the media contents, such as the number of directories indicating how many directories compose the URL, a host address managing digital media contents, and metadata describing directory names and a file name, etc. Therefore, without knowing the explicit URL of digital media contents, users can easily access the media contents through the media object.

Control Object allows users to naturally manipulate

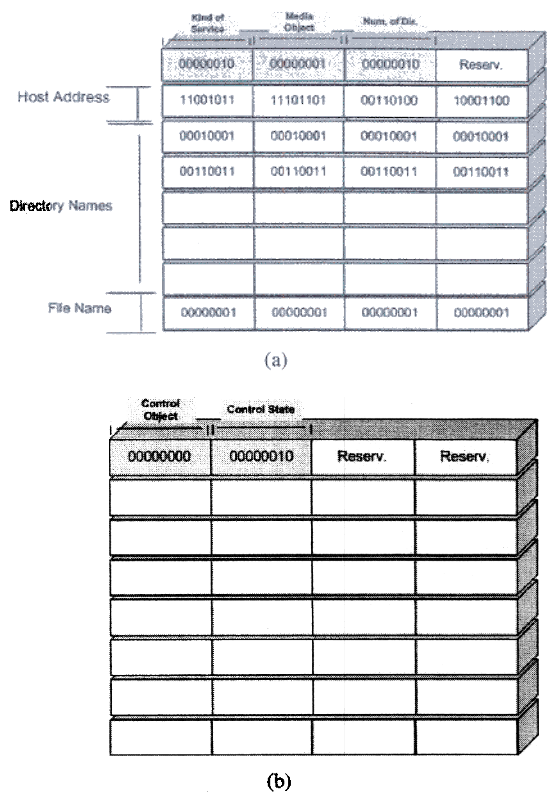


Fig. 2 The memory of RFID tag in tangible objects. (a) RFID tag in Media Object. (b) RFID tag in Control Object.

digital media contents in accordance with users' preferences. It has two kinds of the objects; one is a RFID-enabled object, and the other is a tracker-embedded object. The RFID-enabled object has a RFID-tag attached to each side of a cube. As shown in Fig. 2 (b), the RFID tag contains an identifier of a tangible object, and control state information of a convenient media player. Therefore, by rotating the RFID-enabled control object, users can generate commands to control digital media contents, such as playing, pausing, fast forwarding and rewinding the media contents as well as increasing or decreasing volume of the contents. On the other hand, a tracker-embedded object offers natural interactions, such as weaving or rotating the object, to manipulate the media contents. According to the movement of the user's hands, parameters of a tracker are changed, and then it generates commands to execute complex manipulation of the contents, e.g. selecting musical instruments, and changing a note, playing duration and speed, etc. Therefore, users can intuitively synthesize media contents through the two kinds of control objects.

2.2 Context Recognizer

Context Recognizer detects any changes in state of tangible objects and users, and then creates meaningful contexts by exploiting ubi-UCAM [12]. As shown in Table 1, the generated context is described in the form of 5W1H (Who, What, Where, When, How, and Why) [15]. The Context Recog-

Table 1 Each element of 5W1H.

Context(5W1H)	Context information
Who	User's name, user's ID
What	Object ID, service ID
Where	User's location, service location
When	Event triggering time
How	User's behavior pattern, offered method of the service
Why	User's intention or emotion

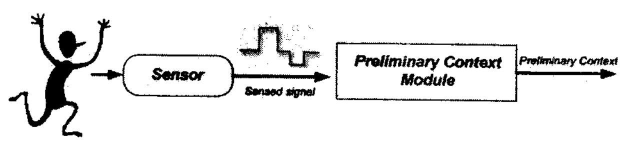


Fig. 3 Transformation from sensed signals to preliminary context.

nizer consists of ubiSensor, an intelligent sensor that forms preliminary contexts from sensed changes; and ubiService, an application that integrates the preliminary contexts and ensures appropriate execution of the media controller.

2.2. ubiSensor

As shown in Fig. 3, ubiSensor senses any changes in environments and makes a preliminary context in the form of 5W1H. Since a sensor has a limited sensing ability, it generates a preliminary context containing only specific elements, which can be extracted from sensed signals, among 5W1H. In the proposed system, we use ubiKey, RF module and tracker module.

The ubikey generates a preliminary context by utilizing a user's profile stored in a USB memory stick [16]. Since it has a specific memory to store data, it can contain personal information, e.g., a user's name and ID, etc. Therefore, the generated context contains the user's name, ID and entrance/exit time.

The RF module creates preliminary contexts of the RFID-enabled tangible objects. That is, if a tangible object exists within an active area of the RF module, it reads data stored in the memory of a RFID tag, and then forms a preliminary context of the object, such as the URL of a media object or control state information of a control object. Moreover, when multiple tangible objects exist within the active range, it recognizes several RFID tags embedded in the objects, and then generates several preliminary contexts of the objects at a time.

The tracker module forms a preliminary context of a tracker-embedded control object by interpreting movements of the object. In the proposed system, it only utilizes four parameters which contain directional information. Thus, according to user's manipulation, such as waving or rotating the tracker-embedded object, the tracker module interprets

Table 2 The preliminary context of ubiSensors.

ubiSensor	Context (5W1H)	Context Information
RF module	What	Metadata of Directory and file name
	Where	Server IP address
	How	Control state
Tracker module	What	Musical instrument / note
	How	Control state
ubiKey	Who	User name / ID
	When	Entrance time

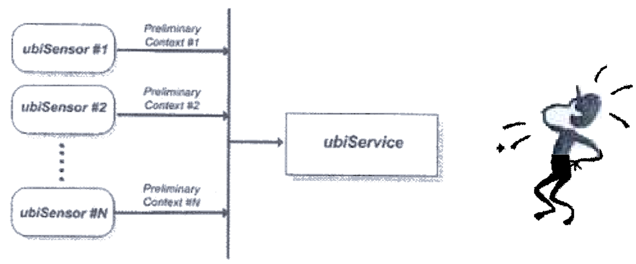


Fig. 4 Mergence of several preliminary contexts in ubiService.

values of parameters to control state information. Table 2 shows the preliminary contexts generated from the three ubiSensors.

2.2.2 ubiService

ubiService, as shown in Fig. 4, integrates preliminary contexts formed by above ubiSensors. In addition, it generates an integrated context reflecting the user's intention as well as a final context containing explicit commands. It consists of Interpreter, Context Integrator, Context Manager and Service Provider.

Interpreter provides an interface to show the list of functions supported by Media Controller, and to let users define conditions and specific functions that must be executed according to the conditions. Context Integrator generates integrated contexts, which contain user's intention, by merging preliminary contexts from RF module, Tracker module and ubiKey every 0.5 seconds. In addition, Context Manager transforms an integrated context to a final context, which is suitable for the media controller, according to the conditions defined by users. Service Provider offers several services suitable for users' situation by executing the specified module of the media controller. Figure 5 shows the data flow between the four components.

2.3 Media Controller

Media controller offers an interactive media composer which allows users to manipulate the media contents. It also

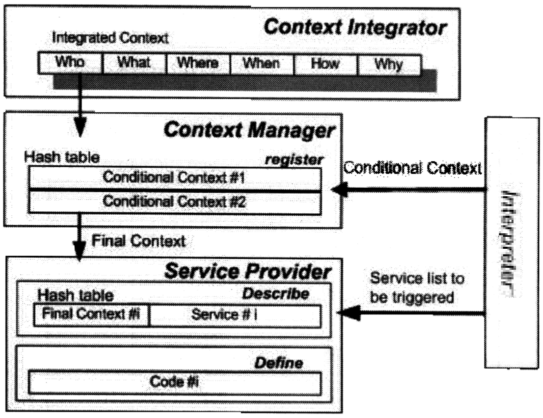


Fig. 5 The data flow between components in ubiService.

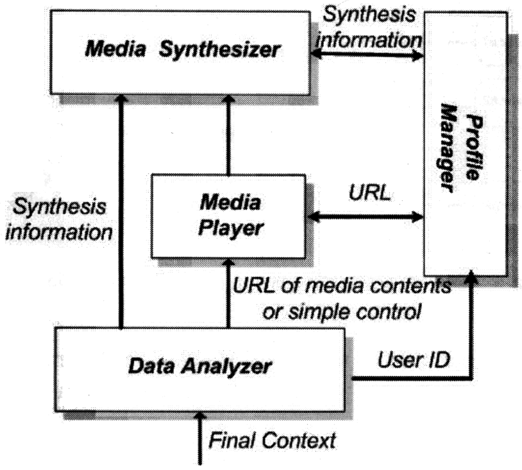


Fig. 6 Media Controller.

provides different media contents according to user's history. As shown in Fig. 6, it is composed of Data Analyzer, Media Player, Media Synthesizer and Profile Manager.

As shown in Fig. 7, Data Analyzer generates the URL or control commands about media contents. At first, it extracts user's information and control state information from the final context generated by Context Recognizer. In order to generate a URL of digital media contents, it also gets a host address, metadata of directory names and a file name from the final context. Then, it accesses database by using the extracted user's information, and finds substantial directories and file name. Finally, it combines them and then completes the URL of digital media contents. In addition, in order to create control commands, it translates the extracted control state information to suitable commands.

Media Player supports a simple control, as a conventional media player, according to results of Data Analyzer. That is, it retrieves digital media contents by using the URL generated from the Data Analyzer. It also allows users to control the media contents e.g. playing, stopping, pausing, fast forwarding and rewinding the media contents, as well as increasing or decreasing the volume of the contents. Therefore, it allows users to easily control the media contents.

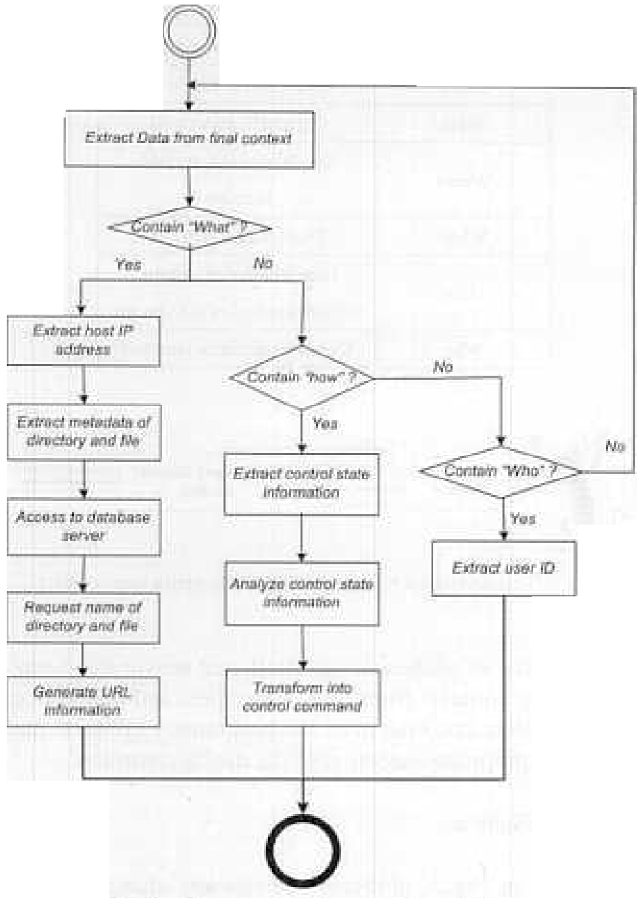


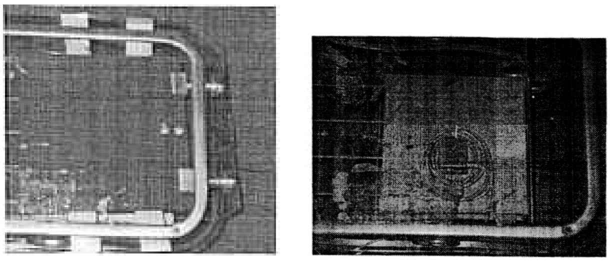
Fig. 7 The sequence diagram of Data Analyzer.

Media Synthesizer offers interactive environments which enable users to flexibly manipulate digital media contents according to their preferences, such as mixing several media contents, inserting sound effects, etc. Moreover, it allows users to select or change a musical instrument or a note of the instrument, and to increase or decrease the playing speed of digital music contents. Users can also select or change the speed and playing duration of a specific note. Thus, it enhances entertainment factors of media contents since it supports various kinds of manipulation.

Profile Manager determines personalized contents suitable for the user's preferences. It maintains history of manipulation, such as URL of played media contents, selected musical instruments and note, etc. Then it analyzes the user's preferences, e.g., preferred musical instruments or media contents, etc. Then, it fundamentally provides different media contents and musical instruments according to the user. For example, when a user accesses it, the specific media contents or MIDI sounds are automatically retrieved according to logs of the user. Thus, it can efficiently satisfy user's expectations about interactions with the contents.

3. Implementation

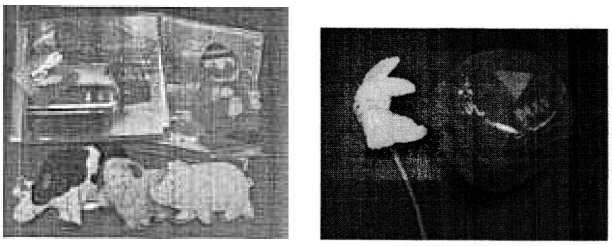
The proposed TMCS is installed in ubiHome [17], a test-



(a) (b)

Fig. 8 The installed modules. (a) RF module. (b) Tracker module.

Fig. 9 System set-up in ubHome.



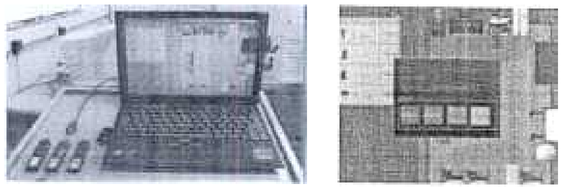
(a) (b)

Fig. 10 Tangible objects. (a) Media Object. (b) Control Object.

bed for a smart home environment. In order to allow users to experience TMCS in the home environment, as shown in Fig. 8, the implemented RF module and tracker module are attached under a table in the ubiHome. Thus, as shown in Fig. 9, users can naturally interact with media contents as they sit on a sofa. It also makes them experience results of manipulation through TV and speakers in the test-bed.

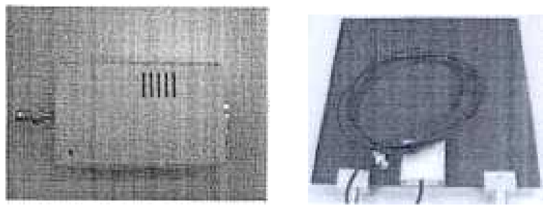
The Media Object, one of the tangible objects, as shown in Fig. 10 (a), embeds a RFID tag (Texas Instrument's transponder, RI-I01-110A [18]) in physical objects(e.g., CD, picture, doll, etc), which people can easily access and use in their daily life. The object allows users to intuitively access media contents, without knowing the detailed information of the media contents. Therefore, digital media contents are automatically retrieved when users put the object onto the table.

As shown in Fig. 10 (b), the Control Object, the other kind of tangible object, can be implemented in two ways; a RFID-enabled object and a tracker-embedded object. The RFID-enabled object attaches a RFID tag, which contains the control state information, and a picture to each side of a cube. The picture depicts the control state information contained in the RFID-tag on the opposite side of the cube. Therefore users can easily know and select a control command through the attached picture. In addition, the tracker-embedded object embeds a tracker in a doll which is easy to use. It allows users to experience various musical instruments and notes by rotating or weaving the object. Therefore, as soon as a user puts the RFID-enabled object onto the table, the related control function is executed. In addition, the MIDI sounds are played out according to movement of user's hands with the tracker-embedded object.



(a) (b)

Fig. 11 ubiKey system. (a) ubiKey. (b) The display at the entrance of ubiHome.

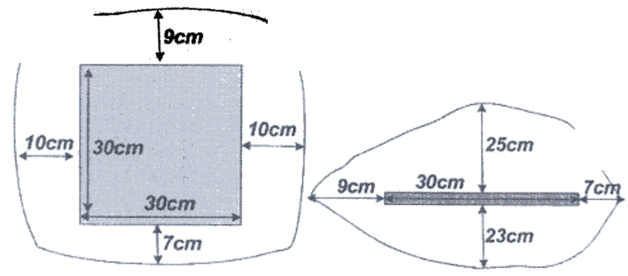


(a) (b)

Fig. 12 The RF module. (a) RF reader. (b) Antenna.

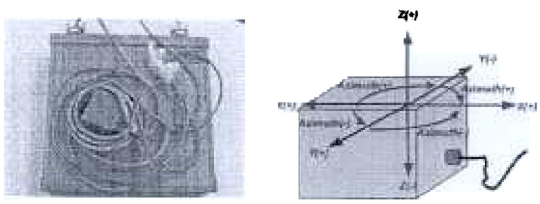
ubiKey, one of the ubiSensors, is implemented by using a USB Flash 16 MB memory stick. Figure 11 (a) shows the implemented ubiKey system [16]. It is portable and can be easily connected to any computers through "plug and play" technique. Since it is installed at the entrance of ubiHome, users can exploit the ubiKey as a general key. As shown in Fig. 11 (b), it also provides an interface which shows a visiting purpose and users' location. Thus, users can know who is presented in the ubiHome and their reason for visiting through the interface.

As shown in Fig. 12, RF module consists of a RFID reader and an antenna (SPARXCOM [19]). In addition, Fig. 13 describes the active range of the antenna whose size is 50 cm (W) $\times$ 46 cm (D) $\times$ 48 cm (H). If a tangible object exists within the range, the RF module reads the data of an embedded RFID tag with 13.56 MHz as the resonant frequency. Moreover, if multiple tangible objects exist within that range, it is implemented to recognize the objects, and to read data of several RFID tags at a time. Then, it simultaneously generates multiple preliminary contexts of the tangible objects. Therefore, it makes users synthesize multiple media contents.



(a) (b)

Fig. 13 The active range of RF module. (a) The front view. (b) The side view.

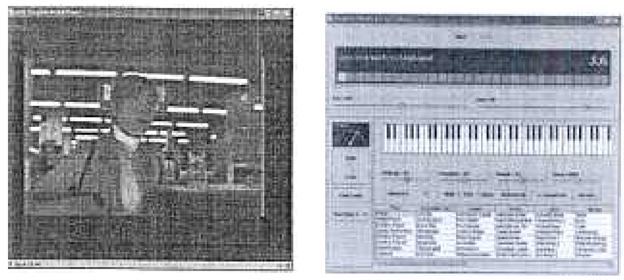


(a) (b)

Fig. 14 Tracker module. (a) ISOTRAK II. (b) The used parameters.

Table 3 The generated control information in Tracker module.

Parameter	Control information
X	Musical instrument
Y	Note value of instrument
Z	Playing duration of note
Azimuth	Playing velocity of note



(a) (b)

Fig. 15 Media Controller. (a) Media Player. (b) Media Synthesizer.

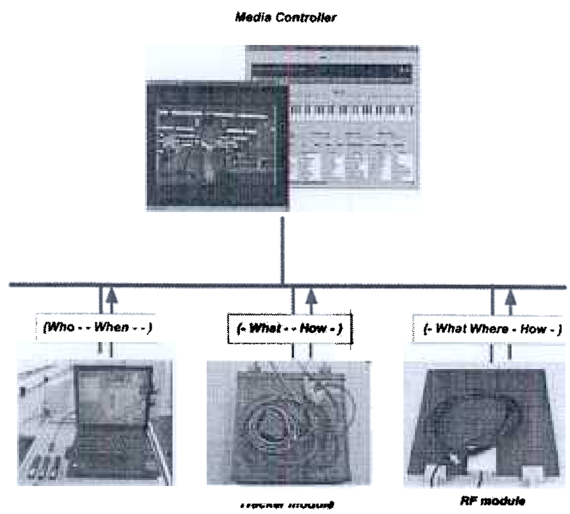


Fig. 16 The relationship between components of TMCS.

Tracker module, as shown in Fig. 14 (a) is implemented by exploiting Polhemus ISOTRAK II [20], which changes six parameters according to the movement of a receiver. In the proposed TMCS, we used and analyzed four parameters, i.e., x, y, z axis, and azimuth, of the tracker. Therefore it generates control commands by interpreting changes in the parameters. Table 3 shows the generated control command interpreted according to each parameter.

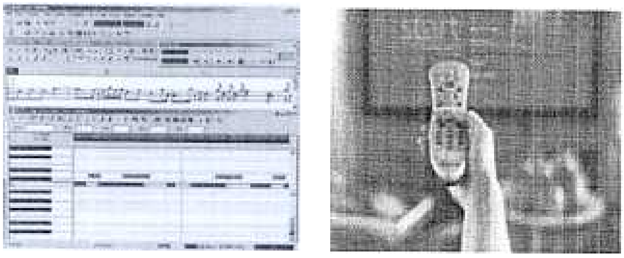
Media Controller is programmed by using J2SE (Java 2 Platform, Standard Edition) 1.4 and JMF (Java Media Framework) 2.1.1. As shown in Fig. 15, Media Player supports various formats of digital media contents (e.g. avi, mpg, qt, etc), and Media Synthesizer also supports various types of digital music contents (e.g. au, rmf, wav, aif, aiff, etc) and MIDI. In addition, a Compaq ML 370 Server (Pentium III 1 G, Dual/1 GB DRAM) manages the media contents and MS-SQL server 2000 is used as database to store information related to the media contents.

Figure 16 describes the complete relationship between components of our proposed TMCS, i.e. connections between implemented ubiSensors, ubiService and Media Controller. That is, the preliminary context of a user generated from ubiKey, and preliminary contexts of tangible objects created by RF module and tracker module are transmitted to ubiService. Then, the ubiService determines proper services to the user. Furthermore, the Media Controller executes a specific module, and offers functions suitable for the user's situation.

4. Experimental Results

To evaluate usefulness of the proposed system, we compared the TUI-based TMCS with the GUI-based SONAR [21] and a remote controller-based media player. As shown in Fig. 17 (a), SONAR is a MIDI Synthesizer that needs a mouse and a keyboard for selecting or controlling music contents. Additionally, in the case of the remote controller-based media player, users can retrieve and control media contents by using a remote controller in Fig. 17 (b).

In order to ensure an unbiased comparison, subjects used the three systems in ubiHome. Then, we performed qualitative and quantitative comparisons between the systems. 20 subjects participated in this experiment. One half of the subjects (group 'A') were in their fifties, and were not familiar with computers, while the other half (group 'B') were in twenties with a good knowledge of computers. Though the number of subjects was not sufficient, we believed that evaluation results at least showed a tendency.



(a) (b)

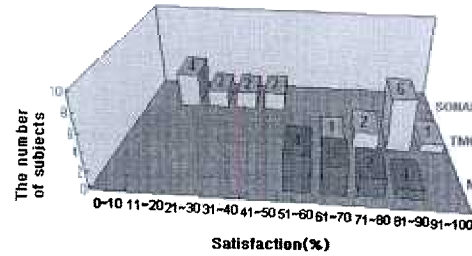
Fig. 17 The compared system. (a) The GUI-based SONAR. (b) The remote controller-based media player.

4. The Qualitative Analysis

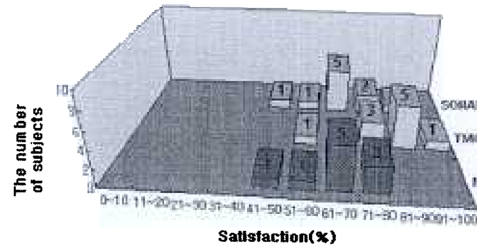
To qualitatively compare TMCS with the SONAR and the media player, 20 subjects used each system for manipulating digital music contents (e.g., several MIDI sounds and musical instruments, etc). Then, we surveyed their satisfaction over the range from 0% (dissatisfaction) to 100% (satisfaction). Questions in the questionnaire were related to control methods, media contents, and functions offered by the systems. Figures 18 and 19 showed the distribution of the satisfaction about the three systems.

Since most subjects of group 'A' were not familiar with computers, they faced difficulties in controlling digital music contents through a mouse and a keyboard. As shown in Table 4, they showed low satisfaction (29.5%) for control methods of SONAR. On the other hand, since they were familiar with a remote controller, they easily exploited the media player through the remote controller. However, as shown in Fig. 18 (a) and Table 4, they expressed the highest satisfaction (84.5%) towards TMCS because they could naturally move their hands to control music contents with tangible objects. We also found that they preferred personalized contents that reflected their latest manipulation since they expressed higher satisfaction for TMCS (83.5%) than for SONAR (68%) and for media player (67%). Moreover, because the media player only offered simple controls (e.g., selecting, playing, stopping music contents, etc), the subjects were more satisfied with various manipulations of SONAR and TMCS. Though two systems allowed them to synthesize several music contents or modify the contents, they showed higher satisfaction about TMCS (75%) than SONAR (58%) since they could easily mix several music contents with their two hands. Therefore, we found that the elderly used tangible objects more easily than a mouse or a keyboard and a remote controller. We also knew that they were content with the personalized contents and functions supported by TMCS.

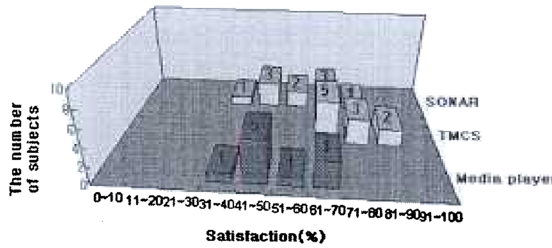
In case of group 'B', as shown in Fig. 19 (a) and Table 5, younger subjects showed the highest satisfaction about control methods (74.5%) among the three systems. The reason was that TMCS allows them to intuitively access music contents by using tangible objects, without any explicit information of the contents. Similar to group 'A',



(a) The control methods.



(b) The offered contents.



(c) The supported functions.

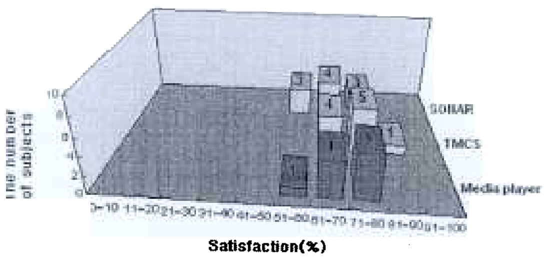
Fig. 18 The distribution of the satisfaction in elder group 'A.'

Table 4 The average of satisfaction in group 'A.'

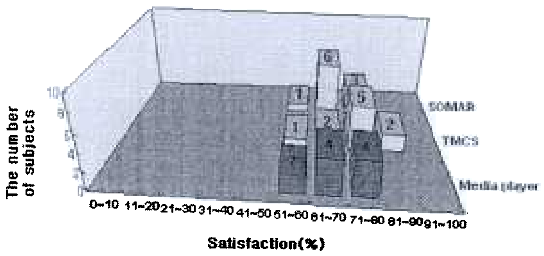
	SONAR	TMCS	Media player
Control	29.5%	84.5%	67.5%
Contents	68%	83.5%	67%
Functions	58%	75%	54.5%

they were also more satisfied with the personalized music contents provided by TMCS (75%) than the contents offered by SONAR (70%) and by the media player (68.5%). Especially, through Fig. 19 (c), we found that they expressed the highest satisfactions for those manipulations offered by TMCS (76%) than provided by SONAR (73%) and the media player (58.5%).

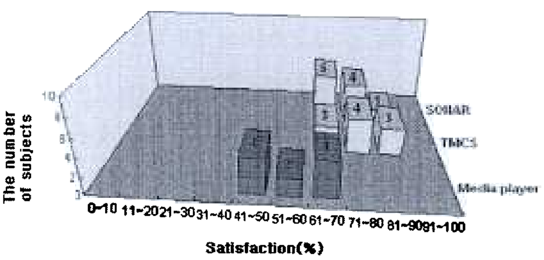
As a result, most subjects showed more satisfaction for the proposed TUI-based TMCS than for GUI-based SONAR and a remote controller-based media player. We found that they were satisfied, because they could naturally manipulate digital music contents by exploiting tangible objects, which were common in their daily life. They also expressed the highest satisfaction about the personalized contents and the supported functions suitable for their taste and preference.



(a) The control methods.



(b) The offered contents.



(c) The supported functions.

Fig. 19 The distribution of the satisfaction in younger group 'B.'

Table 5 The average of satisfaction in group 'B.'

	SONAR	TMCS	Media player
Control	68.5%	74.5%	71.5%
Contents	70%	75%	68.5%
Functions	73%	76%	58.5%

4.2 The Quantitative Analysis

To quantitatively compare TMCS with SONAR and a remote controller-based media player, we measured learning time, selection time and control time. Learning time was the time taken by 20 subjects to learn how to use each system. Selection time was the time spent while selecting media contents. It was measured until the digital media contents were actually displayed on the TV in ubiHome. We also measured control time to exploit a keyboard and a mouse, control objects, or a remote controller for controlling the digital media contents.

As shown in Table 6, group 'A' took more than 13 minutes (801 seconds) to learn how to use SONAR. Moreover, it took subjects about 6 minutes (369 seconds) to know how to use TMCS. On the other hand, they spent about 2 minutes (148 seconds) for the media player. The reason was that

Table 6 The learning/selection/control time in elder group 'A.'

	SONAR	TMCS	Media player
Learning time	801sec	369 sec	148.2 sec
Selection time	366.7 sec	4.1 sec	47 sec
Control time	99.4 sec	2.1 sec	2.2 sec

Table 7 The learning/selection/control time in younger group 'B.'

	SONAR	TMCS	Media player
Learning time	100sec	26.5 sec	32.5 sec
Selection time	25.6sec	3.4 sec	3.9 sec
Control time	2.0sec	1.6 sec	1.7 sec

most subjects of group 'A' were already familiar with a remote controller. However, they did not have any experiences with a keyboard, a mouse and tangible objects. Comparing with tangible objects and the keyboard and mouse, they spent less time for TMCS than SONAR. Additionally, since most subjects of group 'A' made repeated mistakes while using a keyboard and a mouse, it took more than 6 minutes (366.7 seconds) to select digital media contents. They also spent about 99 seconds to control digital media contents. In case of media player, subjects spent 47 seconds to select media contents and about 2 seconds to control the contents. On the other hand, In case of TMCS, since subjects could select digital media contents only by placing media objects onto a table, it took about 4 seconds to do that task. They also spent about 2 seconds to manipulate digital media contents by using the control object. Through these results, we found that the proposed TMCS provides an effective interface to those who are not familiar with a keyboard or a mouse, such as the subjects of group 'A'.

In case of group 'B', younger subjects took about 100 seconds to learn how to use SONAR and about 33 seconds to know the operation of the media player with a remote controller. As shown in Table 7, their learning time for TMCS (26.5 seconds) was much shorter than that for SONAR and media player. Though most subjects of group 'B' were familiar with a computer, selection time for SONAR (36 seconds) was longer than that for TMCS (3.4 seconds). This was because they had to input URL of digital media contents with a keyboard or a mouse. However, there is little difference between control times of both systems, so the subjects did not observe much variation.

Therefore, the proposed TMCS offered more efficient methods for selecting and controlling digital media contents than SONAR and media player. Most subjects spent less time to select and control media contents with TMCS than with SONAR and media player. This was because TMCS allowed subjects to easily access digital media contents without knowing URL of the media contents. By comparing learning time, we concluded that TMCS was also easier than learning the usage of SONAR or the remote controller-based media player.

5. Conclusion and Future Works

In this paper, we present Tangible Media Control System (TMCS), which allows users to manipulate media contents through physical objects in an intuitive way. TMCS proposes a TUI-based interface by using tangible objects which we can easily exploit in our daily life, such as CD, picture, doll, etc. Accordingly, it provides convenient interfaces for users to naturally access and manipulate digital media contents in smart home environment. It also offers personalized contents to a user by utilizing contexts of a user and his or her environment. Moreover, the proposed system supports an interactive environment in which users can manipulate digital media contents according to their taste. Therefore, TMCS can be applied to various applications such as interactive education, entertainment, media editor and so on.

For the future works, we have a plan to do further qualitative and quantitative analysis of the proposed system with more subjects, and to improve the current design of tangible objects. In addition, we plan to consider more effective personalized services according to user's profile history. Moreover, the current system only considers the manipulation of digital music contents. We will extend the proposed system to support other kinds of media contents.

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