A User Study on Information Searching Behaviors for Designing User-centered Query Interface of Content-Based Music Information Retrieval System

내용기반 음악정보 검색시스템을 위한 이용자 중심의 질의 인터페이스 설계에 관한 연구

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ABSTRACT

The purpose of this study is to observe and analyze information searching behaviors of various user groups in different access modes for designing user-centered query interface of content-based Music Information Retrieval System(MIRS). Two expert groups and two non-expert groups were recruited for this research. The data gathering techniques employed in this study were in-depth interviewing, participant observation, searching task experiments, think-aloud protocols, and post-search surveys. Expert users, especially majoring in music theory, preferred to input exact notes one by one using the devices such as keyboard and musical score. On the other hand, non-expert users preferred to input melodic contours by humming.

초 록

본 연구에서는 기존의 시스템 중심의 방식에서 벗어나 각 이용자 집단에게 효율적이고 만족스러운 내용기반 음악정보검색(Music Information Retrieval : MIR)의 질의인터페이스를 설계하고자 각 집단의 음악정보탐색행위를 연구하였다. 연구대상 집단은 음악분야의 전문 지식 여부에 따라 2개의 전공자 집단(작곡전공, 성악/기악전공)과 2개의 비전문가 집단(아마추어 비전문가, 순수 비전문가)으로 구분하여 모집하였다. 모집방법은 연구대상자 선정과정을 포함한 누증표집(snowball sampling) 기법과 이론적 샘플링(theoretical sampling) 기법을 이용하였고 최종적으로 전공자 집단 7명, 비전문가 집단 7명 모두 14명이 실험에 참가하였다. 탐색실험, think-aloud, 참여관찰, 탐색후 질문지법과 심층 인터뷰를 통해 얻은 자료를 분석 및 통합하여 결과를 도출하였다. 작곡 전공의 전문가 집단은 정확한 음렬로 질의를 입력할 수 있는 인터페이스(건반, 텍스트, 악보 입력)를 선호하였고, 비작곡 전공의 전문가 집단과 비전문가 집단은 허밍 질의 인터페이스를 선호하였다. 각 질의 방법의 입력오류를 최소화시키기 위한연구가 더 필요하다.

Keywords : information searching behavior, content-based, query interface, access mode
음악정보검색시스템, 정보탐색행위, 이용자 연구, 내용기반

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1. Introduction

The studies for information needs and information searching behaviors of Music Information Retrieval(MIR) system users are very few(Downie 2003). Almost all of MIRS studies have limitations of system-based retrieval approaches and relevance assessments, and they usually focus on only the development of retrieval tools(Chai & Verco 2000, Roland 2001). Even usability studies of MIR system dealt with user behaviors on the specific MIR systems so these studies could not be devoted to general applications. Even though they can give information on how users behave on existing systems, information of searching motives and strategies of various user groups cannot be given. Furthermore, although a few studies(Cunningham etc 2003, Lee & Downie 2004, Kim & Belkin 2004) contributed to understating music information users, more user studies are required for the development of user-centered MIR system.

The ability of representing queries is different depending on users' characteristics (Uitdenbodgerd & Zobel 1998). This kind of difference must be an important factor especially to implement content-based MIRS. It is because content of music can be difficult for non-experts to understand and memorize. People may have different preferences and performances for retrieving information of content based MIRS depending on their musical knowledge and skills. Therefore, the aim of this study is to investigate various users' searching behaviors in content-based MIRS in order to develop a user-centered query interface.

2. Research Methods

2.1 Sampling Methods

The sampling method of this study is a snowball sampling including screening questionnaire process and theoretical sampling. Snowball sampling is especially useful to gather specific user groups like music experts. However this gathering technique has risks of resulting in a biased sample, so all participants were asked to fill out a 'screening questionnaire', before the experiment. Through this procedure, the researcher can assure that all participants are real users of MIRS who have used it at least twice a week along with the expectation of continual future use. Then participants were recruited until the researcher could generalize the findings from the quantitative and qualitative data for theoretical sampling. In theoretical sampling, the number of participants is not important. Participants are recruited until a researcher concludes the number of them that is enough to generalize the findings. Theoretical sampling is used for grounded theory approach which is the best for the study area which is new or has not been investigated until then(Strauss & Corbin 1990).

Because this study is a new area, the researcher intended to generalize the findings by analyzing and interpreting the

data acquired from searching experiments, participant observations, in-dept interviews and post-searching surveys through the procedure of grounded theory approach.

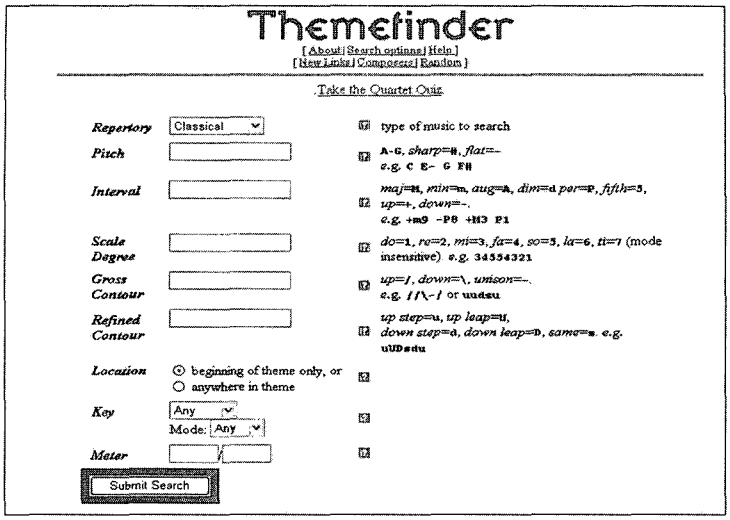
The researcher made 4 groups(two experts groups and two non-experts groups) according to participant's musical knowledge with objectives of using MIR systems. Expert groups were divided into two groups, group A for those majoring in music theory and group B for those majoring in voice and instrument. Also non-expert groups were divided into two groups, group C for amateurs who have some musical knowledge and musical instrument skills, and group D for music listeners who simply enjoy listening to music for pleasure. By using snowball sampling and theoretical sampling, a total of 14 participants were recruited. Group A is composed of three participants, group B four, group C three and group D.

2.2 Research Design

Several qualitative research methods as well as search experiments were adopted because the aim of this research is to understand users and their behaviors to suggest important factors that may affect their preferred query interface.

Before participating in search experiments, each of the participants was asked to fill out a research agreement document and demographic survey. Demographic survey was used as 'screening questionnaire'. Then, the researcher interviewed each of them to find out his/her information needs and observed their individual searching behaviors or strategies. During observation, the researcher asked them to think aloud while they were searching MIRS then recorded think-aloud protocol, writing down important points of his/her behavior. After interviewing, each of participants was asked to conduct searching tasks two times. The object of searching tasks is not only to show the specific numerical value of searching success rate but also to find out significant factors that influence searching behaviors through input error analysis, and to investigate the difference of participants' preferred query types. Almost two hours were spent for each participant.

The first searching task is designed to know users' preferred textual query input mode and the reasons of their choice. The system tool adopted in this study is 'ThemeFinder System' (http : //www .themefinder.com) which provides various textual query input modes. 'ThemeFinder' is a type of content-based MIRS and a non-profit collaborative project of the Center for Computer Assisted Research in the Humanities (CCARH) at Stanford University and the Cognitive and Systematic Musicology Laboratory at the Ohio State University. Currently there are three databases : Classical Instrumental Music, European Folksongs, and Latin Motets from the sixteenth century. Themes and incipit available through 'ThemeFinder' are encoded in the 'kern' music data format. 'ThemeFinder' system has five textual



〈Figure 1〉 Query Interface of 'ThemeFinder'

queries input modes as shown in 〈Figure 1〉. Users put a letter(C, E...) to represent a note for 'pitch' mode, a chord(+m9, +M3...) for 'interval' mode and a number(1, 2...) for 'scale degree' mode. Also to represent melodic contour, which shows the pitch difference between two notes, users can put / - \ for 'gross contour' or U, D, S for 'refined contour.'

The researcher spent about 5 minutes explaining the method of using this system because participants had no experience of using content-based MIRS, in fact participants had never even heard about it. The researcher tried to make real situations where users do not know musical titles or composers and only know theme melodies. It was because in this situation people are most likely to use content-based MIRS(Downie 2003). So if they have real information needs, the needs for searching music of which they only remember theme melodies, researcher asked them to make their own query. However if they did not have that kind of query, they were asked to make a query using the presented music, 'Air on the G string.' Each participant was required to input the same query using five input modes of the 'ThemeFinder' system which were cross-presented to them.

The object of the second searching task is two-fold. One is to find out the difference of users' abilities to make queries of monophony, homophony and polyphony according to user groups. The other is to investigate the most preferred query input mode among humming, keyboard, pictorial score, melodic contour and textual input modes. Especially the textual input mode is what each participant chose as the most preferred textual mode during task I. Each participant was asked to choose four queries among eight. He/she had to choose

〈Table 1〉 Query sets for searching task II

	Query Type	Query No.	Music Title
Monophony	QA	QA1	Six suites for solo cello No.1 Prelude (Bach)
Homophony		QA2	Sonatas, arpeggione, piano, D. 821, A minor 1 Movement Allegro Moderato (Schubert)
		QA3	Air on the G string (Bach)
		QA4	Arioso (Bach)
		QA5	Ave Maria, op. 52 no.6 (Schubert)
Polyphony	QB	QB1	Brandenburg Concerto No. 2 in F Major 1 Movement (Bach)
		QB2	Spring, op. 8 no.1 from "the four seasons" (Vivaldi)
		QB3	Trout-Quintets, op. 114 in A major, for piano, violin, viola, cello and bass or 2nd cello 4 movement (Schubert)

〈Table 2〉 Query input modes for searching task II

Input Mode	Feature	Method
Textual input	visual clues (text or symbol)	To record the most preferred textual input mode using 'ThemeFinder' System
Humming input	Audio clues	To record sung queries of participants who are asked to sing pronouncing 'DaDa…' (Meek etc 2002)
Keyboard input	visual and audio clues	To ask participants to input melodies by playing the web-based keyboard (http://chak2lang.com/piano.htm)
Pictorial score Input	visual clues	To ask participants to input queries on the score represented on a software tool to draw
Pictorial contour input	visual clues	To ask participants to draw melodic contours using a software tool

two from query type A and two from query type B as shown in 〈Table 1〉. Then each participant made four queries using the five input modes in 〈Table 2〉.

The researcher asked each participant to speak his/her thoughts, feelings and difficulties during searching tasks and recorded think aloud protocols. After each searching task, all participants were asked to fill out a post-search survey designed to

know users' preference to each query input mode.

After all, in chapter 4, the researcher intended to organize the data acquired from search experiments, observations, think-aloud, post-search surveys, and interviews.

2.3 DATA ANALYSIS

With the accurate query input, in the first searching task, if the right answer is retrieved within top 10 search results of Theme Finder System, the search was judged to be successful. For the second searching task, evaluation process was manually conducted by the researcher through comparing the query submitted by participants and musical scores. Because of key transposition, queries made by participants and melodies written on the scores can be different even in same theme melodies. So, the researcher took this into consideration. In case of pictorial score query input mode, pitch as well as rhythm were considered for evaluation.

A total of 280 query inputs (14 participants × 4 queries × 5 input modes) were evaluated for analysis. The researcher re-evaluated theses presented queries at an interval of 15 days. Consistency rate was 95.78%.

Data from a think-aloud protocol, post-search survey and in-depth interview were analyzed by content and later used to analyze and interpret the results of experiments. All data were organized to theorize information searching behaviors in chapter 5.

3. Results

3.1 Participant Information

Participant information was acquired from demographic surveys. Participants are similar in age, length of time in using computers, experience of using MIRS, and frequency of using MIRS. And none of them had experience of using content-based MIRS.

Participants of group A and B were graduate students of music department of Yonsei and Kyunghee universities in Korea. Group B for those not majoring music theory was composed of one person majoring in voice, one majoring in violin, and two majoring in piano. Group C, comprised of amateurs, have experiences in performing at orchestra for more than three years, and have played musical instruments for more than six years.

Following results are represented through analyzing and interpreting the data acquired by searching tasks I and II, observations, think-aloud protocols, interviews and post-search surveys.

3.2 Preferred Query Input Mode by User Groups

Through a post-search survey, it was found that all participants' clue of remembering music was a theme melody,

〈Table 3〉 Preferred query input mode by groups

	Textual	Humming	Keyboard	Pictorial (score)	Pictorial (melodic contour)
Group A	3.67	2	**4.33**	3.67	1.33
Group B	1.25	**4.75**	4	2.25	2.75
Group C	2.33	**4.33**	3.67	1	3
Group D	3	**4.75**	2.75	1	3

and they usually made queries using the first phrase or repeated phrase or climax in case of a song.

The most preferred input mode scored '5' and the least preferred one as '1'. Because the number of each group's members was different, the final score was averaged in 〈Table 3〉.

3.2.1 Group A : music theory students

By the result of a post-search survey, it was found that the most preferred query input mode of group A members was the keyboard input mode. Textual mode and pictorial score mode had the same scores then humming mode followed. And the least preferred mode was pictorial melodic contour input mode. Through interviewing, it was found that the reason why they chose the keyboard input mode as the best option is because many are familiar with using the keyboard due to their major. They could easily and correctly represent queries from memory. Among various textual query input modes, 'Pitch' method was the most preferred because they could input exact notes one by one. On the other hand, they disliked 'Refined Contour' method using U, D, S. They thought this method is difficult to represent theme melodies and have the potential to create many incorrect search results. Many content-based MIRS were implemented with U, D, S index. This kind of system however, may be uncomfortable to expert users.

3.2.2 Group B : Voice and instrument students

In case of group B, the most preferred query input mode was humming input. Next were keyboard, pictorial melodic contour, pictorial score input mode, and textual input mode. The reason why they chose humming query input mode, as the best one, is that they can sing easily without any special efforts. One voice student answered that he usually remembers melodic contours but not exact notes while the student majoring in piano preferred the keyboard mode because of her major.

This group preferred 'Gross Contour' method, using '/ - \' to represent melodic contour. However, they all agreed that it is

difficult for them to represent queries using textual input mode because they find it confusing. Also, some of them said that they could not input exact notes one by one correctly due to their lack of a sense of sound and 'Interval' method was difficult to those majoring non-theory since they do not study harmonics deeply.

3.2.3 Group C: Amateurs

For group C, the most preferred query input mode was humming input too. Next were keyboard, pictorial melodic contour, and textual input mode. And the least preferred query input mode was pictorial score input mode. Like group B, the reason why they chose the humming input as the best mode was that they could easily represent queries by singing without any special efforts. And the reason why they liked keyboard input mode was that they can listen what they input and correct their queries at the same time. On the other hand, no one could input queries correctly using pictorial score input mode because it is very difficult for them to pick the exact notes.

The most preferred textual input mode was 'Gross Contour' method, representing melodic contours with '/-\', because they could make queries without knowing the exact pitch. And one participant suggested that to represent '+ = -' is better than '/-\' because the former is more intuitive than the latter.

3.2.4 Group D: Common music listeners

In case of group D, like Group B and C, humming query input mode was the most preferred. Textual input mode, and pictorial melodic contour mode had the same score. Next was keyboard input mode and the pictorial score input mode was the least preferred mode.

They had difficulties in entering exact notes due to their lack of musical knowledge and a sense of sound. So they preferred melodic contours to exact notes. The reason why they preferred the 'Gross Contour' method to the 'Refined Contour' is that graphic symbols like '/-\' are more intuitive than U, D, S. Ultimately, they encountered difficulties in representing melodies with the textual symbols.

3.3 Accuracy Rate for Representing a Query by Groups

Each of participants was asked to make a total of 20 queries with 4 query types and 5 input modes. To abandon a searching task due to the lack of a sense of sound was considered a failure or incorrect input. The accuracy rate for representing a query is averaged as in 〈Table 4〉. Except pictorial melodic contour input mode, group A, music theory students, had the highest percentage in all input modes. Then group B, C and D followed. Non-expert groups, group C and D, did not even attempt to input queries using pictorial score mode. Even though the participants are all regarded as musical experts, the difference

〈Table 4〉 Accuracy rate for representing a query by groups

	Textual	Humming	Keyboard	Pictorial (score)	Pictorial (melodic contour)
Group A	58%	58%	58%	58%	17%
Group B	56%	56%	56%	50%	25%
Group C	42%	50%	33%	0%	42%
Group D	13%	44%	6%	0%	19%

in accuracy existed between music theory students (group A) and voice and instrument students (group B).

3.4 Factors Affecting Query Input Errors

Through the analysis of query representation inputted, think-aloud protocols, post-search surveys and interview, the factors that affect query input errors of content-based MIRS were found as follows : personal factors, input mode factors, musical factors and emotional factors.

3.4.1 Personal factors

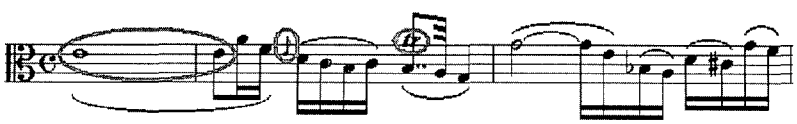
Besides the lack of musical knowledge and a sense of sound, the amount of memory clue and familiarity with a theme melody affected the input errors. When users had more memory clues, they could represent a query more easily and correctly. To represent or recall a melody requires already memorizing or knowing the melody. That is, in the context of MIR, recognition of a melody is meaningful only if one can memorize it, and the only melody recognized is the one that is remembered.

3.4.2 Input mode factors

Even though some of experts could not make correct queries because of their lack of a sense of sound, it should not be concluded hastily that this factor only affects input errors. It is because that each of the input modes has its own features to create user input errors. The representative examples of the errors are as follows.

3.4.2.1 Textual query input ('/-\')

In case of 'Air on the G String' of Bach,



〈Figure 2〉 G on the String (input error of textual query mode)

the correct query as a theme melody using the 'Gross Contour' method is '/\\\\\/\\\···'. However the most frequent queries submitted by those who inputted wrongly was '-/\\\'. They should have inputted the first symbol of a query with the consideration of the pitch difference between notes. However, they inputted '-' instead of '/' because the first note continued for a long time. Also, those who did not consider ornament in the second phrase could not get relevant results from 'ThemeFinder' system.

3.4.2.2 Humming query input

Through the analysis of input errors using humming, four phenomena of expansion, compression, repetition and omission of some notes were found. These findings are the same as McNab' s study(McNab etc 1997).

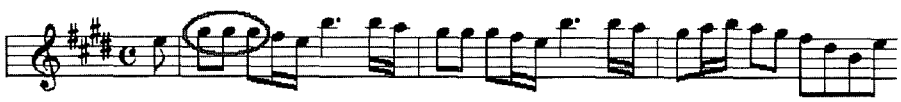
3.4.2.3 Pictorial melodic contour query input

Almost all of the groups had low accuracy rate using pictorial melodic contour query input. They especially made errors of repeating or omitting when musical notes sequences rise or drop and same notes sequences emerge. For example, a participant inputted an incorrect theme melody of 'string from the four seasons' in spite of success using other input modes. In marked notes of 〈Figure 3〉, the same pitch note repeats three times, so the correct representation of melodic contour is '– –', but she inputted '– – –'.

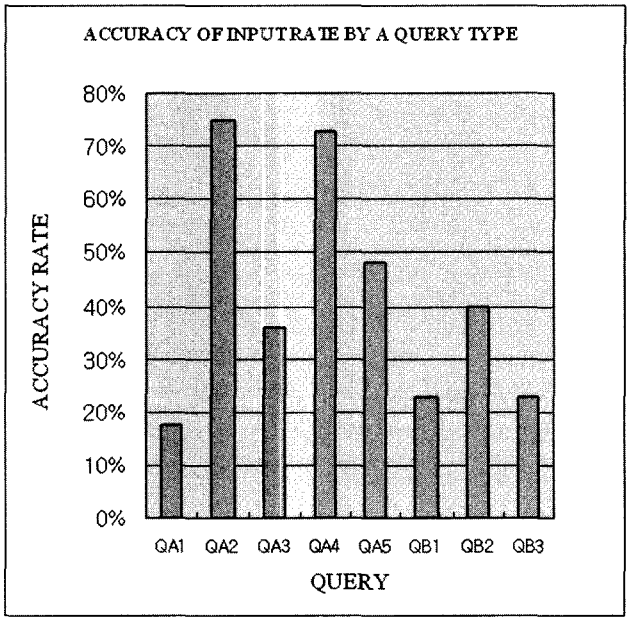
3.4.3 Musical factors

Through the analysis of accuracy input rate, QA1, QA3, QB1 and QB3 had a low rate as shown in 〈Figure 4〉. In case of QA1, even though 'six suites for solo cello No. 1 Prelude' in 〈Figure 5〉 is very famous and familiar to participants, this query had the lowest rate. Even exert group inputted wrongly CGEDEDEG or DABABABG instead of inputting correctly CGEDEGEG or DABABGBG using textual input mode. The reason of the failure was compression of the fifth note and the sixth note or repetition of the fourth note and fifth note.

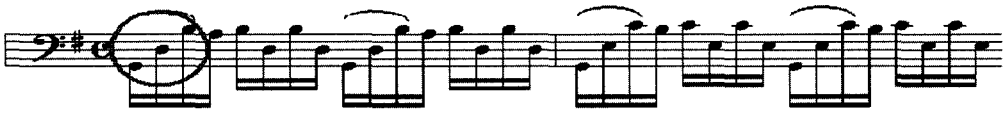
Also, some participants commented that it was difficult to use the keyboard input mode because the interval of the first three notes is rather large. Through this response, it was found that the interval degree of notes sequences might affect the level of difficulty of input. Although monophony music is usually expected to have a better rate than homophony or



〈Figure 3〉 String op.8 no.1 from "the four seasons" (input error of pictorial melodic contour mode)



〈Figure 4〉 Accuracy of input rate by a query type

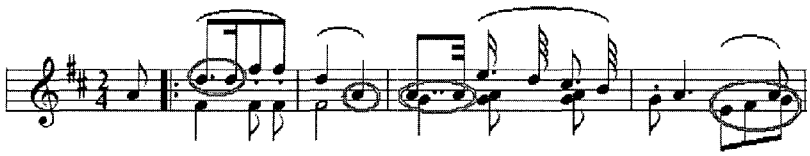


〈Figure 5〉 Six suites for solo cello No.1 Prelude

polyphony, the accuracy rate of input was not affected only by complexity of harmony.

The music of 'G on the String', GA3, is homophony music that a string instrument plays a theme melody. In 〈Figure 2〉, the first note lasts long with the piano's accompaniment. Some of participants were confused with this accompaniment when inputting a theme melody. Also, an ornament and a trill in the second phrase seemed to confuse many participants.

Even though the music of 'Trout-Quintet' in 〈Figure 6〉, QB3, is also familiar to users, it had a low rate. In the marked notes of the first and third phrase, following the incomplete bar, some of participants put together the separated two notes that have same pitch and different rhythm. This incorrect input would be affected by a lower part. And in some cases, the second note of the second phrase was inputted repeatedly. Also, a combination of an upper and lower part appeared in the fourth phrase as it was found in the study of melody extraction of polyphony(Uitdenbodgerd 1998).



〈Figure 6〉 Trout-Quintets

3.4.4 Emotional Factors

One participant said that she could remember the theme melody of 'arpeggione sonata' easily, because it was so impressive and heart moving to her. This shows that emotions or impressiveness aroused by music can be a factor influencing memory and representation of theme melodies. However, this finding must be supported with further studies for theorization.

4. Music Information Searching Behavior

Wilson(1999) defined information searching behavior as the interaction between users and other users or users and computer systems in the context of information seeking behavior. In this study, the researcher operationally defined music information searching behavior as the interaction between users and music information retrieval systems. And in this study, 'browsing' which is a kind of information searching behaviors is not commented.

4.1 Approach using Parsons code (UDS) and other textual symbols

Participants approached music information using Parsons code(1975) and other textual symbols like '/-\' when they do not know lyrics as well as titles or composers. Expert groups who have the most abundant knowledge in music like to input exact notes, one by one. They preferred inputting pitch name (C, D, E…), scale degree (1,2…) and interval. On the other hand, groups majoring in voice and instruments and non-expert groups disliked inputting these kinds of symbols because of their lack of musical knowledge and a sense of sound. Instead, they preferred to search using melodic contours, which use the symbol '/-\'. However, most participants responded that it is difficult for them to represent queries if they only remembered theme melodies.

4.2 Approach using pictorial query

An approach using pictorial query input mode was not preferred compared to other approaches. It was impossible for those who have little musical knowledge to search music by drawing pitch and rhythm on a score. Even in the case of pictorial

melodic contour mode, participants were likely to commit errors such as repeating and omitting specific notes.

Music theory students preferred inputting pitch and rhythm on a score, while voice and instrument students and non-expert groups preferred drawing melodic contours. The tools to make users input queries more intuitively and easily are strongly needed.

4.3 Approach using humming

Almost all of the participant groups preferred humming query input mode because of the easiness to input. Especially, participants majoring in voice or instrument and non-expert groups preferred using this approach. The reason of preference is that they can make queries without any efforts and check their queries while concurrently singing a query. However, those who lack of a sense of sound resulted in serious input errors.

4.4 Approach using keyboard interface

Keyboard query input mode has certain advantages of using visual and audio clues. Users can listen to their queries and modify them by checking its relevance. However, this mode was difficult for non-expert groups due to their lack of musical knowledge and a sense of sound. On the other hand, expert groups preferred a keyboard input. It is strongly required to develop an integrated keyboard query interface for expert users so that they can input pitch and rhythm easily and accurately.

5. Conclusion

The findings about music information searching behaviors of various user groups in different access modes can be used for a user-centered query interface design of content-based MIRS.

Suggestions based on the findings of this study are as follows. The query interface fitted to users' characteristics and preference should be provided. Expert users, especially majoring in music theory, preferred to input exact notes one by one using the devices such as a keyboard and a musical score. On the other hand, non-expert users preferred to input melodic contours by humming. Furthermore, a query interface to minimize input errors should be developed. More deep studies about factors that affect input errors are needed for system development.

This study has the limitation of small participants. So this point may make the findings difficult to be generalized or theorized. However, this study is a kind of exploratory study, and it is based on a grounded theory approach. Also various qualitative research methods contributed to drawing findings beyond numerical values.

To develope user-centered MIRS, quantitative studies using larger sample sizes and more in-depth user studies about each user group are needed.

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