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MUSICFX: An Arbiter of Group Preferences for Computer Supported Collaborative Workouts

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ABSTRACT

Environmental factors affecting shared spaces are typically designed to appeal to the broadest audiences they are expected to serve, ignoring the preferences of the people actually inhabiting the environment at any given time. Examples of such factors include the lighting, temperature, décor or music in the common areas of an office building. We have designed and deployed MUSICFX, a group preference arbitration system that allows the members of a fitness center to influence, but not directly control, the selection of music in a fitness center. We present a number of empirical results from our work with this intelligent environment: the results of a poll of fitness center members, a quantitative evaluation of the performance of a group preference arbitrator in a shared environment, and some interesting anecdotes about members' experiences with the system.

Keywords

Intelligent environments, ubiquitous computing, shared spaces, human-computer interaction, social behavior, social interactions, empirical studies, evaluation, audio, audio spaces.

INTRODUCTION

We spend much of our time in shared environments – spaces in which two or more people are in close proximity and are mutually affected by tactile, olfactory, visual, and aural factors such as temperature, scents, lighting, and background noise. These factors are increasingly under the control of computers embedded in our environments. Combined with a growing variety of sensors that can detect people and their activities, these new capabilities allow for the design of intelligent environments. This new paradigm results in a shift of perspective: from viewing people as *users* of computers to a view of people as *inhabitants* of environments. One way that an intelligent environment can respond to its inhabitants is by adjusting itself to better suit the inhabitants' needs or preferences.

Traditionally, environmental factors in the common areas of a workplace are affected in one of the following manners:

?? They may be held fairly constant, e.g., the décor in a hallway or entrance area.

?? They may be varied based on a clock, e.g., lowering the temperature late at night.

?? They may be controlled by a single person, e.g., turning on the lights in a conference room.

In each case, some thought is typically given to the expected preferences of the people affected by the environmental factors, and one can imagine instances in which explicit preferences might be sought ("Does anyone mind if I open a window?"). However, the growing proliferation of embedded computers provides an opportunity to explore the prospect of a more systematic way of taking explicit preferences into account.

MUSICFX is a system that adjusts the selection of music playing in a fitness center to best accommodate the musical preferences of the people working out at any given time. The system has a database of fitness center members' preferences for a wide range of musical genres, a mechanism for identifying who is working out at any given time, and an algorithm for selecting a musical genre that will promote members' listening pleasure.

This research grew out of the juncture of two concurrent threads in the authors' experience. One is a perception that most of the research in ubiquitous computing has focused on ways that an environment might respond to a single individual rather than a group of people. The other is a

frustration with the "lowest common denominator" music typically played in a fitness center on a daily basis.

The group preference agent embodied in MUSICFX is not limited to selecting music in a fitness center, however. It is applicable to any shared environment in which people gather for an extended period of time. For example, a restaurant provides another type of environment that might benefit from a group preference agent, however an elevator would not be a good candidate. Furthermore, the approach is applicable to environmental factors beyond music or other auditory input: visual, olfactory and tactile factors could also be adapted to the set of people assembled in a particular location. Finally, the set of preferences for each individual might either be explicitly specified by each person, or inferred based on knowledge of the person's behavior, e.g., a shopper's purchase history.

In the sections that follow, we will describe the fitness center environment in which MUSICFX operates, provide an overview of how the system works, present the results of a poll we have conducted to assess the popularity of MUSICFX among fitness center members, describe a quantitative evaluation of the performance of the system based on comprehensive logs of all events of interest, and conclude with some interesting interactions we have observed between members and the system.

THE FITNESS CENTER ENVIRONMENT

The music played in a fitness center provides for an ideal laboratory in which to experiment with a group preference agent. People are gathered together in a common location, each performing separate (though related) activities that do not typically require much attention. Since the foreground activities are not engrossing, background environmental factors become more important. Most people want to hear *some* music while they are working out; the problem for the staff of a fitness center is to decide which music to play.

The fitness center at the Accenture Technology Park (ATP), called the Fitness Xchange (FX), is located in the lower level of our Northbrook facility, and is open to all ATP residents from 6:00 a.m. through 8:00 p.m. each weekday. The FX has 24 cardiovascular machines (treadmills, stationary bikes, stair climbing machines, and so on), 14 strength-training machines and an assortment of free weight equipment. The number of people working out ranges from a high of around 25 at peak times (before work, lunchtime, and after work) to one or two people during mid-morning and mid-afternoon hours.

ATP subscribes to the PrimeStar™ direct broadcast satellite service, which includes the Digital Music eXpress (DMX ©) music service, providing 91 stations of commercial-free music, each representing a different musical genre. The variety of genres includes Album Rock, Classic Jazz and Symphonic, as well as Flamenco Music, German Oldies and Beach Party. Prior to the installation of MUSICFX, the FX staff manually selected DMX stations; this manual selection process was complicated by the fact that the room containing the satellite receiver is located in another part of the building, resulting in relatively infrequent station changes.

The FX is the most popular service at ATP, with over 600 members among the Park's 1500 residents. However, despite the general popularity of the FX, the music played in the FX was a source of controversy, accounting for 50% of the verbal complaints made by members to the FX staff and 25% of the written "suggestions" submitted anonymously by members. There are a small number of members who are quite willing to express their preferences for (or, more often, against) different types of music, and in the absence of input from the less vocal members, there tended to be a "squeaky wheel syndrome" where the complainants got their way. This factor, combined with the inconvenience of physically changing stations, resulted in only three stations – the ones that generated the fewest complaints – being played, out of the set of 91 possible stations.

The primary research goal of MUSICFX is to explore the social ramifications of a group preference agent in a shared environment, i.e., whether a system that controls an environmental factor based on people's preferences can prove socially acceptable. Related to this research goal, our more pragmatic goals for the MUSICFX system are to:

?? *Democratize the music selection process*. Accommodate the silent majority rather than the vocal minority, resulting in greater listening enjoyment for FX members. The more vocal members may not be pleased as often, but the less vocal members will now have their voices "heard".

?? *Increase the variety of music played*. Provide airtime for the stations outside of the lowest common denominator set. Members who work out at off-peak hours may now be able to listen to music that would never be played when larger numbers are present.

?? *Offload the music selection task from the FX staff responsibilities*. Enable the staff to spend more time attending to fitness related matters rather than acting as disc jockeys.

While these goals focus on the issue of music selection in the context of a fitness center, they have broader applicability. The idea of democratizing the control of a common environmental factor could be applied to lighting or temperature levels. While people probably would not enjoy rapidly fluctuating lighting and temperature levels, increased variety in the décor of common areas might be a welcome change. Finally, any person who shoulders the burden of controlling a highly controversial environmental factor could benefit from a system that arbitrates among diverse preferences.

Having described the environment in which the MUSICFX system operates, let us now turn to a description of the system itself.

THE MUSICFX SYSTEM

The MUSICFX system runs on two Windows 95™ computers that are linked via the ATP local area network. One computer, which we call the DMX computer, is located in the room that houses the DMX satellite receiver: it has an infrared (IR) remote control device attached to its serial port. The other computer, the FX computer, is located in the FX: all the software modules described below reside on this computer. When the system selects a new station, it sends a command from the FX computer to the DMX computer, which translates it into a channel change signal sent to the IR remote control device.

MUSICFX provides two interfaces accessible on the FX computer. The *FX member interface* allows members to login to the system, to update their preferences for any station, and to provide us anonymous feedback about the system. The *FX staff interface* allows the staff to monitor the system, manually select new stations and to adjust certain parameters that will be described below.

Underlying these interfaces, the FX computer hosts three components that enable the operation of the system: a database of FX members' musical preferences, a mechanism for identifying who is working out in the FX at any given time, and an algorithm for selecting one among the 91 genres of music that will promote members' listening pleasure. This algorithm is invoked each time an event occurs, e.g., a member enters the FX to begin a workout. Each of these components is described in greater detail below.

Preference Database

In order for a group preference agent to make an informed decision about how to affect environmental factors, it must know something about what the current inhabitants prefer. In MUSICFX, each FX member specifies his or her preference for each musical genre. The preference rating for a genre is represented by a number ranging from +2 to –2; Figure 1 provides an interpretation for each of these levels of preference.

Rating	Interpretation
+2	I *love* this music
+1	I *like* this music
0	I *don't mind / don't care about* this music
-1	I *dislike* this music
-2	I *hate* this music

Figure 1. Rating Scale for Musical Genres

A member submits an electronic MUSICFX enrollment form upon first joining the fitness center; the FX member interface also contains an update screen that permits a member to enter or update his or her musical preferences in the fitness center at any time.

Presence Detection

A group preference agent must know the composition of the group – who are the current inhabitants? – in order to make decisions about how to adjust environmental factors. Members login to MusicFX by swiping their ATP badges across a proximity badge reader. In case a member loses his or her badge, the system also permits members to login manually, using the same login ID they use for logging their fitness activities at a separate computer maintained by the FX staff.

Group Preference Arbitration Algorithm

The group preference arbitration algorithm takes as input an M x N table of integer-valued preferences ranging from –2 to +2, where M is the number of categories being rated (musical genres) and N is the number of inhabitants (FX members who are currently working out). For each category i, and each member j, that member's individual preference for that category ($IP_{i,j}$) is used by the algorithm to compute the overall group preference for that category (GP_i) using the following summation formula:

$$GP_i = \sum_{j=1}^{N} (IP_{i,j} + 2)^2$$

The formula first converts all individual preference ratings to non-negative numbers, so that we can later apply a weighted random selection operator (described below). These values are then squared in order to widen the gap in selection probabilities between the more popular categories and the less popular categories.

Once this group preference value is computed for each category, the list of values is sorted in descending order, such that the most popular category is first and the least popular is last.

We considered the policy of always selecting the top category, but since most people typically workout at the same time each day, they would tend to hear the same music under this scheme (unless they update their individual preferences). The second most popular station might be the favorite among a few of those people, but it may never be played. Therefore, the system uses a weighted random selection policy for selecting one of the top m stations (we call this the *candidate set*), where m is a parameter whose value is set by the FX staff.

Figure 2 depicts a set of sample preferences for five people (A through E) and ten musical genres. The group preference value calculated for each genre (GP_i) is shown in the second column from the right. Assuming that m=3, i.e., the candidate set is limited to the three most popular genres, the probability of selecting each genre (Pr_i) is shown in the rightmost column. The sum of the GP values for the three most popular genres is 141, so the probability of selecting

the most popular genre, Alternative Rock, is 0.48, nearly twice the probability of selecting the third most popular genre, New Music.

i	*Genre* *Person*	A	B	C	D	E	GP_i	Pr_i
1	Alternative Rock	2	2	0	2	2	68	0.48
2	Hottest Hits	1	1	2	0	-2	38	0.27
3	New Music	1	1	1	0	0	35	0.25
4	Hot Country	2	0	0	0	-2	28	0.00
5	Dance	2	-1	1	-1	-1	28	0.00
6	World Beat	0	1	-1	1	-2	23	0.00
7	Traditional Country	1	0	0	-2	-2	17	0.00
8	50's Oldies	0	0	0	-1	-1	14	0.00
9	Heavy Metal	-1	-1	-1	-1	-2	4	0.00
10	Polka	-1	-1	-2	-2	-2	2	0.00

Figure 2. Sample Preferences

Note that if these five people were to work out at the same time each day, simply choosing the most popular station would mean that person C would always listen to music that he or she does not particularly like (nor dislike). Using the weighted random selection algorithm would allow this person to listen to music that he or she likes (New Music) or loves (Hottest Hits) some of the time.

Events

There are five events that trigger the execution of the group preference arbitration algorithm:

?? Member Entrance

?? Member Exit

?? Individual Preference Update

?? System Parameter Adjustment

?? Maximum Station Play Time Elapsed

Each time one of these events occurs, the algorithm is run, and if the currently playing station is no in the candidate set, a new station is selected.

Member Entrance

As mentioned earlier, members either swipe their ATP badges or manually login at the computer. When a new member enters the FX, his or her preferences must be added to the pool of preferences used in the group preference calculation, so this login process triggers the Member Entrance event.

Member Exit

We decided not to require explicit logouts to trigger Member Exit events, for fear that people might forget to logout at the end of their workout sessions; another consideration was that the music plays both in the fitness center and the adjacent locker rooms, and we wanted members' preferences to still be considered while they are in the locker rooms. A survey revealed that the average duration of a workout, including locker room time, is 70 minutes, with a standard deviation of 20. We decided it was better to continue to include some members' preferences after they finish working out than to exclude some members' preferences while they are still working out; therefore, we set a default time of 90 minutes for the duration of a workout session. After this time, a Member Exit event is triggered, and that member's preferences are removed from the pool of preferences considered in the group preference calculation.

Individual Preference Update

Whenever a member updates his or her preferences, the pool of preferences (the set of individual preferences associated with the group of people currently working out) considered during the previous invocation of the algorithm is no longer valid. Such an update often occurs when a member decides he or she dislikes or even hates the currently playing station, even though he or she had previously specified a more positive rating for that station. After the individual preference update, the group preference value for the currently playing station would then decrease, possibly so far as to cause the current station to fall outside the candidate set. Since we don't want the current station to continue playing in this case, we trigger an Individual Preference Update event to force the algorithm to run again.

System Parameter Adjustment

When the FX staff changes a system parameter, e.g., narrowing the range of top-rated stations to be considered, the currently playing station may or may not remain in the candidate set, so a Parameter Adjustment event is triggered.

Maximum Station Play Time Elapsed

Due to the diverse, and sometimes conflicting, musical tastes of the FX members working out at any given time, we recognize our inability to please all the people all the time. One situation that we endeavor to avoid is "starvation" – one or more members never hearing music they enjoy due to the differences between their music preferences and those of the majority of people with whom they regularly workout. The weighted random selection operator is one strategy we use to reduce the likelihood of starvation. Another strategy used is to limit the period of time that any one genre will play – regardless of how popular it is – before the selection algorithm is invoked in order to select a new station. A Maximum Station Play Time Elapsed event is triggered when the specified period of time elapses.

System Parameters

The FX staff can constrain the operation of the MUSICFX system by adjusting any of the following three parameters:

?? Individual Preference Filter

?? Group Preference Filter

?? Maximum Station Play Time

Each of these is discussed in more detail below.

In addition to a set of controls for the parameters listed above, the interface for FX staff also provides the capability to manually select new stations to play at the press of a button (rather than having to walk down the hallway to another room). The FX staff interface also includes a button to turn off the algorithm, requiring manual intervention by the FX staff for all subsequent station changes.

Individual Preference Filter

A primary motivation behind MUSICFX is to increase the listening pleasure of the FX members working out at any given time. This can be accomplished by playing more of the music that members want to hear or by playing less of the music that members do not want to hear (ideally, both). One way to ensure that the system plays less music that people do not want to hear is to prohibit the system from playing any station for which anyone present has specified a low rating. The system provides the FX staff a way to specify an individual preference filter threshold between 2 and –2; any station for which a present member has specified a preference value below the threshold is eliminated from consideration by the algorithm. For example, a threshold setting of –1 prohibits any station for which anyone currently working out had specified a rating of –2 (i.e., at least one member hates this kind of music).

Group Preference Filter

The group preference filter parameter (the variable *m* in the group preference formula listed above) allows the FX staff to specify how many of the top-rated stations are considered candidates for the weighted random selection procedure. The possible values range from 1 to 91, where 1 forces the system to select the top choice each time and 91 permits the system to select any station (though selection of popular stations would be more probable than selection of less popular stations). This parameter was included to give the staff some control over the variability of the music being played. Most FX members follow fairly regular workout schedules, e.g., Monday, Wednesday and Friday from 7:00 to 8:00 in the morning; thus, many of the same people work out at the same time each day. If the system always chose the top-rated station, then members would be likely to hear the same station every time they work out. While we still permit this policy – with a group preference filter setting of 1 – we also allow the music selection to vary among the set of most popular stations.

A group of stations with the same group preference value forms an equivalence class. The group preference filter threshold may arbitrarily partition such an equivalence class: some members of equivalence class will be included in the candidate set, while the rest are excluded. If there were a fixed ordering within an equivalence class, the stations that occur earlier in the ordering would tend to be played more often than those that occur later in the ordering. Therefore our sorting routine ensures that stations within an equivalence class are randomly distributed within each segment of the sorted list. This is especially important since, as noted before, the regularity of member workout times combined with a constant group preference filter would result in the same stations being prohibited each day.

Maximum Play Time

The period of time that any one genre can play without interruption is limited by the maximum play time parameter, which varies between 1 and 60 minutes. We have used an initial setting of 30. Coupled with our estimate of workout sessions lasting 90 minutes, on average, this results in at least three genre changes – for a total of at least four genres that will be played for any one member's workout

POLL RESULTS

Six weeks after we installed MUSICFX, we conducted a survey to find out how well the members liked the music being played in the fitness center. We asked members whether they thought the music being played was better, worse or the same, compared to before the system was installed. We also asked them to tell us the things they liked most, and the things they liked least, about the system.

We received a total of 71 responses, which represents more than 25% of the members considered active[1] at the time we conducted our poll. The responses are summarized in Figure 3.

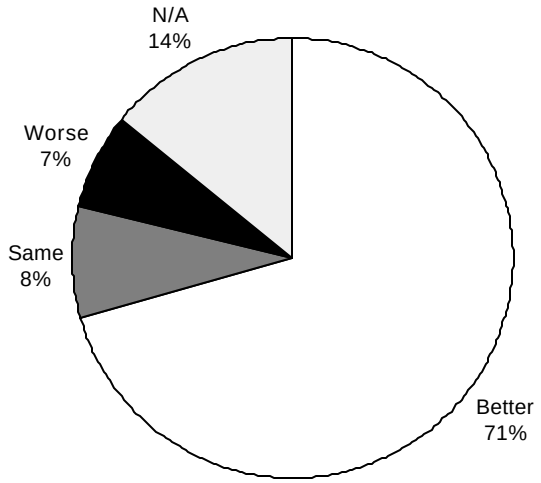

Figure 3. Popularity of MusicFX

The vast majority of the respondents (71%) said they like the music selected by MUSICFX better than the music that had been played prior to the installation of the system, and only a small fraction of the people (7%) thought the music is worse. A few people (8%) thought the music was about the same, and there was a final group of people (14%) who had

[1] A member is "active" if he or she has worked out at least once in the preceding month.

joined the fitness center after MUSICFX was installed, and thus were unable to answer that question.

Nearly half of the respondents told us that they enjoyed the increased variety of music played by MUSICFX. A third of those responding told us that they liked having some influence in the selection of music. One fourth told us that they liked the "good music" played by the system. Other popular aspects of the system include exposure to new music, being subjected to "bad music" less often, and the elimination of disputes over the music since the system was installed.

MUSICFX currently has no mechanism for detecting song boundaries, so it often changes stations abruptly in the middle of songs; this shortcoming was cited by a third of the respondents as one of the least popular features. The "occasional" selection of "bad music" was a complaint among fifteen percent of our survey participants, a side effect of the greater variety of music played. Eight percent of the respondents told us that MUSICFX did not exhibit *enough* variety in its selection. Three people said the stations changed too often, while one said they didn't change often enough, and three people complained about the offensive lyrics heard on the Rap station.[2]

QUANTITATIVE EVALUATION

We are encouraged by the apparent popularity of MUSICFX, based on the results of our poll. However, we also wanted to take advantage of the extensive logs being kept by the system, and undertake an in-depth evaluation of how well the music played by the system corresponds to members' stated preferences.

In this section, we describe the data we used in the evaluation, the metrics we developed to measure the performance of the system, and the results of this evaluation.

Evaluation Data

MUSICFX maintains three log files:

?? An *event log* that is updated for each of the five system events listed above (member entrance, member exit, individual preference update, system parameter adjustment, and maximum station play time elapsed).

?? A *preference log* that is updated each time a member makes changes to his or her ratings for any of the 91 stations.

?? A *feedback log* that is updated each time a member submits anonymous feedback through the member interface.

The data we used for the evaluation was drawn from the first two log files, which are described in more detail below. The feedback log is a text file into which comments typed in by members on a special pop-up window are anonymously written. It has only been used a few times, and the comments are similar to those mentioned above in the section on poll results.

Event Log

Every event that has some potential effect on the system is tracked in the event log. Over 5000 events were logged during the initial six-week period. Each entry in the event log includes several fields:

?? *Date* and *time*.

?? *Type* of event, e.g., member entrance.

?? *Member IDs* of the people present, in the order of their arrival.

?? *System parameter values*: settings for the individual preference filter, group preference filter and maximum play time.

?? *Station* currently playing.

?? The *status of each station*, including the station ID, the group preference value (GP_i) for that station, and a prohibited flag that indicates whether the station is currently a member of the candidate set or prohibited (based on the individual preference filter or group preference filter).

?? *Reason* for station change (if applicable), e.g., to distinguish between station changes due to a timeout (based on the maximum play time parameter) from those due to the currently playing station falling out of the candidate set (based on a change in group preference values due to the entrance or exit of a member).

Preference Log

Each preference log entry includes the date and time of the entry, the member ID and name of the person updating his or her preferences, the new set of ratings for each station, and a flag indicating whether this is a new member enrolling in the system with an initial set of preferences or an existing member updating an established set of preferences.

Evaluation Metrics

The data collected in the MUSICFX log files provides us with the opportunity to evaluate a broad range of issues concerning the behavior of the system – especially with respect to its selection of stations – and its effect on people.

Statistics Gathered about People

Our primary goal in evaluating the data contained in the logs is to quantitatively assess the satisfaction of members,

[2] Due to the nature of some of the Rap lyrics, which were deemed inappropriate in a business setting, we were asked to disable the selection of this station by MUSICFX, leaving us with 90 candidate stations. Since this change occurred after the evaluation period covered by this paper, we will continue to refer to 91 stations.

by comparing their preferences to the stations to which they were listening while in the fitness center. However, we are also interested in the distribution of ratings for different musical genres, and how that distribution changed over time.

To compute the satisfaction of members over the first six weeks, we extracted information from both the event and preference logs. For each member entrance event, we tracked the stations that were selected for that member during that 90-minute *session*, and how long those stations played during the session. We then determined the member's rating (-2 to +2) for each station at that time, and multiplied the member's rating by the length of time the member listened to that station. Dividing this number by the duration of that session gives us the *session satisfaction* for that member on a scale of –2 to +2. The average satisfaction for that member over the entire six-week period can be found by simply taking the average of all session satisfaction values. The average satisfaction for the 170 members who logged into the system during the six-week period is shown in Figure 4.

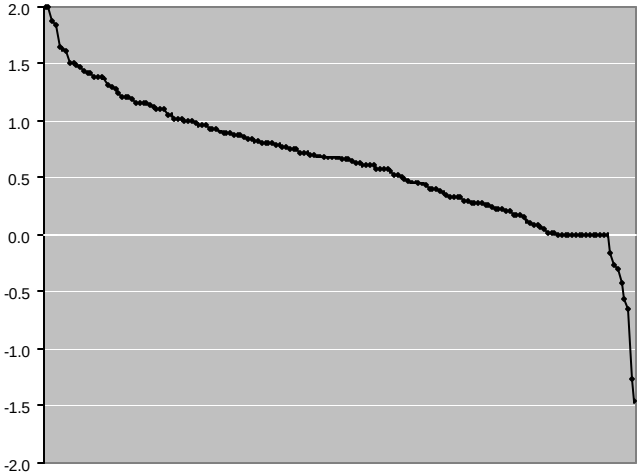

Figure 4. Average Satisfaction of FX Members

All but eight members have non-negative satisfaction values, and the vast majority of members have positive satisfaction values. Of the eight members who appear dissatisfied, i.e., have negative satisfaction levels, five had logged in fewer than five times, and can reasonably be expected to achieve higher levels of satisfaction over time. The other three members each specified a rating of –2 for 88 out of 91 stations, and therefore might be considered difficult to satisfy, with respect to their musical tastes.

We computed the overall satisfaction with MUSICFX as the average of all per-session average satisfaction values for all member sessions. For the six-week period we examined, the overall satisfaction rating was 0.64 (again, on a scale of –2 to +2). Prior to the installation of the system, the selection of music was fairly evenly distributed among three stations (Hottest Hits, Power Hits and Dance); based on our logs, we estimate that the overall satisfaction of members would have been 0.44 during this period had the previous distribution been in effect. It is interesting that what appears to be a modest gain in our satisfaction scale is still significant enough that the vast majority of people polled report that the selection of music is better than before.

We are also interested in the distribution of people's musical preferences, i.e., how many stations people generally love, like, dislike and hate. We computed the average preference for each person by multiplying each preference rating (-2 to +2) by the number of stations with that rating, and taking the average of those values. The distribution of average members across all members is shown in Figure 5 (the dashed lines indicate changes in preferences).

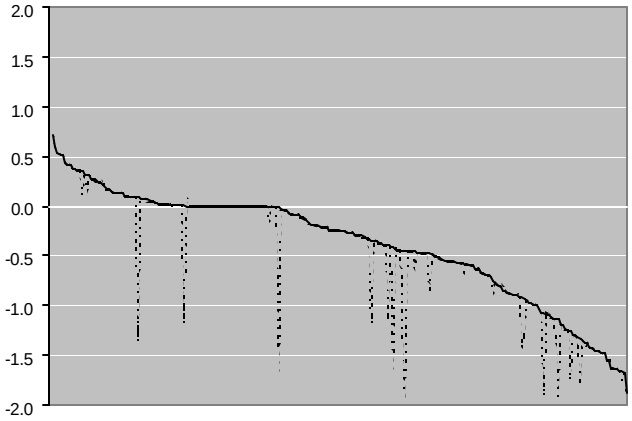

Figure 5. Average Preferences of FX Members

For the initial preference database, the average preference for all members was –0.38, confirming our hypothesis that people tend to hate or dislike more types of music than they love or like, at least while they are working out. Over the six week period, fitness center members tended to lower their ratings for various stations: 103 individual preference update events were logged, and the average preference for all members decreased to –0.44 at the end of this period. The three dissatisfied individuals mentioned above have the three lowest average preference levels of all members.

Statistics Gathered about Stations

The primary focus of our evaluation was on how the behavior of MUSICFX affected people working out in the fitness center. However, we were also interested in which stations were being played, and how well these stations were liked by the people listening to them. Therefore, we also collected statistics about the individual stations.

The first thing we wanted to find out was how often different stations were being played. Figure 6 shows the top 10 most frequently played stations, along with the percentage of time those stations were played.

Station	Percent of Total Airtime
Alternative Rock	14.3
Album Rock	9.0
Power Hits	8.6
Classic Rock	7.9
Hit Sweep	7.7
80's Music	7.6
Hottest Hits	7.5
Dance	6.5
New Music	4.4
Adult Contemporary	3.6

Figure 6. Top 10 Stations

The three stations previously played – exclusively – in the fitness center are among the top 10 stations most often selected by MUSICFX (these are italicized in Figure 6). However, it is interesting to note that the two most popular stations had not been played before, there are five stations more popular than two of the three "old" stations, and the three "old" stations are only played 23% of the time now that MUSICFX is selecting music.

In the first six weeks of operation, 77% of the airtime in the fitness center has been devoted to these top 10 stations. However, the system has played a variety of music, selecting 66 of the available 91 stations at least once during this period. This greatly increased variety is enjoyed by many, though not all, of the members, as shown in the features cited by members responding to our poll. It has also led to a variety of interesting situations that we have observed (or heard about) in the fitness center since MUSICFX was installed.

EXPERIENCES WITH MUSICFX

The community of people who work at ATP, and who workout at the fitness center, is a technology-savvy crowd. Most members in the fitness center are quite at ease with using the MUSICFX member interface, and several have shown great interest in attempting to manipulate the system to get "their" music to play.

When we first installed the system, we recommended that the fitness center staff set the Individual Preference Filter to –1 so that the system would never select a station that was hated by one or more members present at any given time. Unfortunately, on the first day, each author separately observed a different member – at different times – who learned that whenever someone changed the rating for the currently selected station to –2, the system would change the station immediately. We therefore recommended that the Individual Preference Filter be set to –2 (essentially, turned off). One of the aforementioned individuals was observed the next day showing off his newfound manipulative capabilities, only to be frustrated by the system no longer responding to his preference changes.

Since then, the staff has experimented a few times with setting the Individual Preference Filter to –1, but this nearly always resulted in the candidate set dwindling to one or two stations, and sometimes to zero[3], whenever the number of members present approached ten. Given the heavy negative bias of members' musical preferences, it appears that the Individual Preference Filter is best not used (set to –2).

Another example of members' efforts to manipulate the system was a situation in which two members decided to see if they could cause the system to select the Polka station (Polka and Opera are tied for least popular station among fitness center members). Both members changed their ratings for the Polka station from –2 to +2. However, since there were seven other people working out at that time, most of whom [presumably] had a rating of –2 for the Polka station, two people increasing their ratings was not sufficient to put Polka into the candidate set of stations considered by MUSICFX. In fact, Polka is among the 25 stations that have not yet been selected by the system.

One member, with rather broad musical tastes, and who tends to work out during off-peak hours, has been surprised by the responsiveness of the system. He has been treated to Brazilian Music, Flamenco Music, Hawaiian Music, and a variety of other stations that are not commonly played in the fitness center. However, when other people are present, he has in some cases changed his rating on some of these stations so that stations that are more widely popular could be played instead.

Another member observed a situation in which Chinese Music was selected during a time when few people were working out. While this genre might not normally be considered workout music, one of other people present commented favorably on the music, and expressed an interest in learning more about this type of music. MUSICFX thus has increased members' awareness of the variety of musical genres.

In addition to the members' experiences, the FX staff has also had positive experiences with the system. One FX staff member reports that complaints she has received about the music have decreased from several per day to a couple per week. Another staff member says the complaints she has received have declined from five to ten per week down to a total of three since the system was installed. Although we provided several parameters through which the staff could influence the operation of the system, the two staff members with whom we spoke reported changing system

[3] The system has a default station, which can be set by the fitness center staff, that determines what station is selected when the candidate set is empty, a situation that arises whenever the fitness center is empty.

parameters only a few times, and that our default settings appear to work quite well.

The FX staff members have been enthusiastic supporters of the system since we began our initial discussions regarding plans for MUSICFX. Arbitrating among the diverse musical preferences of the fitness center members was one of the most dreaded aspects of their jobs; the increased satisfaction of the FX members has translated into a big increase in the job satisfaction of the FX staff.

RELATED WORK

A number of researchers [Hill and Terveen, 1996; Shardanand and Maes, 1995] have explored the idea of collaborative filtering, which involves inferring preferences of a user based on the preferences of other, similar, users. This inference is used to make a selection that typically affects only a single user directly. MUSICFX differs from these systems in that our system uses explicit preferences of all inhabitants to make a selection that will directly affect everyone who is present.

Other researchers have explored how environments might sense and respond to inhabitants, but most of them have focused on single inhabitants.

The Olivetti Active Badge™ system [Hopper, *et al*., 1993; Want, *et al*., 1992] provides a mechanism for locating and tracking individuals throughout a building using infrared badges and a network of transceivers. The system, as originally designed, did not include a representation of preferences, and was primarily focused on how artifacts (computers, doors, or telephones) might respond to an individual rather than a group. However, this kind of technology could be quite useful in the MUSICFX system, since it would eliminate the need for a manual login or a preset timeout to trigger entrance and exit events – the system could simply poll periodically for the presence of active badges in the fitness center and locker rooms.

The Xerox PARCTAB system [Want, *et al*., 1995] also provides a mechanism for locating and tracking people who are carrying a handheld device. One application allows individual inhabitants of a room to vote on the quality or pace of a presentation using their PARCTABS; the presenter can then respond to this feedback, but the environment itself does not respond to voting. A PARCTAB could be used to control the lighting or temperature of a room – much as we can change channels with a television remote control device – but it does not appear that the designers were concerned with using this functionality in rooms with multiple inhabitants.

The Responsive Environment Project at Xerox [Elrod, *et al*., 1993] explored how an environment might conserve energy by adjusting the lighting and temperature, based on an awareness of who was present (or scheduled to be present) in offices and common areas within a building. This work differs from MUSICFX in that it was basically a two-state system – an office or common area was either empty or non-empty – and the preferences of the inhabitants was not considered in its control strategy.

The Intelligent Room at MIT [Coen, 1997] is able to track multiple inhabitants in the room, and supports a number of methods for inhabitants to give commands to the room. While it has some capability for noting individual preferences (e.g., not playing Mozart as someone is dozing), it has no explicit mechanism for arbitrating among preferences of a group of people.

The Reactive Room [Cooperstock, *et al*., 1997] is a shared telepresence environment which responds to its inhabitants, and has a mechanism for storing preferences for videoconference equipment usage. This work focuses on a very difficult problem – how a shared *virtual* environment might better adapt to its inhabitants, where the inhabitants are distributed across multiple physical sites. One way that the room reacts is to adjust a remote camera based on someone leaning left or right; however, it is not clear how the room would react to different people leaning in different directions simultaneously.

Cooperstock, *et al*. [1997], posit four important factors that affect any intelligent environment: the invisibility of the technology, the capability of manually overriding the system, a mechanism for providing feedback to users, and an ability to adapt to the preferences of users. MUSICFX meets all four of these criteria: other than requiring manual login, the system does not require conscious interaction on the part of the FX members, e.g., requiring people to input their preferences each time (or voting on each song); the FX staff can manually override the station selected by the system at any time; the primary feedback that the system provides is in the selection of music played, but the system also provides some feedback to each member with respect to how well the member's preferences align with those of the current group; finally, the system's primary purpose is to continually adapt to the preferences of a changing group of people working out in the FX.

CONCLUSION

Our experience with MUSICFX has shown that an intelligent environment can sense and respond effectively to the preferences of its inhabitants. The vast majority of fitness center members who are affected by the actions of MUSICFX are happy with the system, both by their own account and according to a quantitative assessment of what they have been listening to. People appreciate the ability to influence their environment, and we expect that this appreciation will extend to other environmental factors.

Fitness centers are not the only environments where adaptation to personal preferences might be beneficial. Any environment in which groups of people are gathered for significant periods of time – say, more than 15 minutes – and in which it would be preferable to listen to or watch

something rather than nothing is a candidate for this approach. For example, restaurants might more effectively cater to their customers by playing music that the customers really want to hear, rather than music that the staff thinks the customers want to hear (or music that the restaurant staff wants to hear). Perhaps the issuance of frequent diner's [smart] cards could include musical preferences, as well as culinary preferences and other factors that might help make the restaurant's atmosphere and service more personalized.

Music is not the only environmental factor that could beneficially adapt to a group of inhabitants. Visual displays might adapt to a group of shoppers in a store, or perhaps in a region of a store, promoting items that are likely to be of interest to the current group. User preferences in this case might be inferred from the purchase history of the shoppers rather than explicitly requested, since shopping goals vary more frequently than music preferences. In fact, shoppers might be encouraged to identify themselves to such a system – using smart cards or some special courtesy card – by the prospect of a MUSICFX system that will play the music that they want to hear while shopping.

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