USING JWEBMINER 2.0 TO IMPROVE MUSIC CLASSIFICATION PERFORMANCE BY COMBINING DIFFERENT TYPES OF FEATURES MINED FROM THE WEB

Gabriel Vigliensoni
CIRMMT
McGill University
gabriel@music.mcgill.ca

Cory McKay
CIRMMT
McGill University
cory.mckay@mail.mcgill.ca

Ichiro Fujinaga
CIRMMT
McGill University
ich@music.mcgill.ca

ABSTRACT

This paper presents the jWebMiner 2.0 cultural feature extraction software and describes the results of several musical genre classification experiments performed with it. jWebMiner 2.0 is an easy-to-use and open-source tool that allows users to mine the Internet in order to extract features based on both Last.fm social tags and general web search string co-occurrences extracted using the Yahoo! API. The experiments performed found that the features based on social tags were more effective at classifying music into a small (5-genre) genre ontology, but the features based on general web co-occurrences were more effective at classifying a moderate (10-genre) ontology. It was also found that combining the two types of features resulted in improved performance overall.

1. INTRODUCTION

The field of music information retrieval (MIR) has benefited greatly from the explosion of information that is available on the Internet. The musical information that can be mined from the web is extremely rich in both depth and breadth, and the on-line contributions of both musical experts and general listeners has provided music researchers with a rich resource of cultural information. This information can be accessed not only via traditional web mining approaches like web scraping and crawling, but also via powerful APIs provided by a variety of on-line organizations, such as Last.fm [19] and Yahoo! [20]. This information is of particular value to researchers in automatic music classification, as they can harvest it in the form of numerical features that can then be processed by machine learning algorithms in order to automatically label music with categories associated with domains of interest such as genre, mood or listening scenario.

This paper has two main foci. The first is an investigation of the relative utility of features mined from the web in general and features mined from listener tags, in this case from Yahoo! and Last.fm, respectively. This investigation involves genre classification experiments based on features derived using the APIs provided by these two organizations. The classification effectiveness of each of these two groups of features is analysed both individually and in combination. Results derived from several different feature extraction configurations are also studied, as different configurations can have an important impact on results, but this area has not been methodically investigated to date in the MIR literature.

The emphasis on genre classification in this inquiry is due to the fact that it can be a particularly difficult type of classification that examines the effectiveness of various classification approaches. Although genre classification can certainly have value in and of itself [11], the ultimate goal of this research is to evaluate approaches that can, hopefully, be effectively extended to other types of music classification as well.

The second primary focus of this paper is the presentation of jWebMiner 2.0, a feature extraction tool for mining data from the Internet. This tool has been expanded since the publication of the original jWebMiner 1.0 [12], and the updated version is presented here to the MIR community for their research use. jWebMiner 2.0 was used to perform all of the experiments described in this paper.

2. BACKGROUND INFORMATION

2.1 Mining the Internet for Musical Features

There has been too much research on mining useful information from the Internet to cite with any completeness here. It is, however, valuable to emphasize certain particularly influential papers, namely [2, 5–10, 16–18].

2.2 Social Tags

As noted in by McKay and Fujinaga [11], genre (and other types of musical categories) can be strongly characterized by how an audience understands and perceives music and musicians, not just on objective content-based characteristics. This has important implications for genre classification. "True" class labels are essentially specified by the opinion of millions of listeners and evolve over time. These labels are influenced by many cultural factors, some of which may be independent of purely sonic musical characteristics. The labels that one might assign to a song are based not only on the song itself, but one's overall perception of an artist. Furthermore, it might be said that there is no one ground truth, as is the "truth" is indeed the sum of the opinions of all listeners.

"Social tags" are unstructured text labels assigned by non-expert users to an entity, such as a song, an album or the collected work of an artist. A variety of on-line services, such as Last.fm, permit users to aggregate their tags for a variety of musical resources. There are typically no restrictions on the choice of words or phrases that users can tag resources with, although users do in practice often seem to select tags that other users have already used, thus creating a kind of shared and navigable system [10]. Tagged resources can therefore be said to, in some way, share certain characteristics with other resources that have been tagged with the same category or categories in the perception of users [1]. The value of social tags increases when they are aggregated into such a large public access community repository, as they provide access to information on how all the users of the system perceives and organize the resources [8]. In the context of musical communities and libraries, social tags are used by people for playlist organization; personal song retrieval; the expression of taste and opinion; and general contribution to public knowledge [10].

It is clear that social tags are a source of valuable human-generated contextual knowledge about music. They provide researchers with information about mood, emotion, genre and other types of categories that are based on the subjective perceptions of millions of users [3]. Mining this data from the web can thus be effective in acquiring information that can be used in the evaluation and training of MIR systems, and at least in the short term, as the aggregation of cultural perceptions that are in constant flux as culture and individual opinions change [12].

2.3 Last.fm

Last.fm is a music service that has been in operation since 2003. Internet radio is the core service that it offers to its users, but it also provides them with a broad range of additional functionality. For example, Last.fm allows users to create personal profiles and contribute social tags to songs, albums and artists. Of particular interest, Last.fm automatically generates custom radio playlists using recommendation algorithms based primarily on collaborative filtering. These algorithms consider both user tags and listening behaviour, as mined by Last.fm's "Scrobbler" software, which monitors the music played by listeners both on the Last.fm site and on their enabled local media players.

The amount of information managed by Last.fm is enormous, consisting of more than 39 billion tracks scrobbled to date, a number that is increasing at a rate of over 400 million tracks per week.[1] The company provides free access to portions of its data through an API [19], something that permits developers to build their own tools.

[1] http://www.last.fm/community

2.4 jWebMiner and jMIR

jWebMiner [12] is part of the jMIR automatic music classification research suite [14]. In addition to jWebMiner, jMIR also includes tools for extracting features from audio files and MIDI files; a machine learning engine based on metalearning; datasets to serve as ground truth for training and testing classification models; and software for profiling and detecting metadata errors in music collections. jMIR is designed specifically to facilitate the integration of information extracted from different types of musical data, and jWebMiner is the component that provides access to social context features (i.e., cultural musical information) available on-line.

jWebMiner, like all of the jMIR software components, is designed to be usable by users with both technical and non-technical backgrounds, and as such includes an easy-to-use and flexible graphical interface. All of the jMIR components, including jWebMiner, are open-source and available for free at http://jmir.sourceforge.net.

At its most basic level, the original jWebMiner 1.0 operates by accessing Yahoo's web search API to acquire hit counts for various search strings. For example, calculations measuring how often the names of different musicians or composers co-occur on the same web pages (taking into account how often they occur individually) can provide insights on the relative similarity of the musicians to each other. Similarly, the cross tabulation of song or artist names with musical class labels associated with genre, or mood, for example, can be used to classify music. Of course, basic hit counts can result in noisy data, so it is necessary to include additional processing to improve results.

jWebMiner begins by parsing either iTunes XML, ACE XML, Weka ARFF or text files in order to acquire strings to use in searches. Users may also manually enter search strings in the GUI. The software then accesses Yahoo's API to either measure the co-occurrence of each value in one field with other values in the same field, or to measure the cross tabulation of values in different fields.

The optimal statistical procedure for processing hit counts and dealing with noise contained in them can vary depending on the task at hand. One must consider not only the accuracy of an approach, but also its search complexity, as web services typically involve daily limits on queries. jWebMiner therefore allows users to choose between a variety of metrics and scoring systems.

One option offered by jWebMiner is the ability to allow users to specify "string synonyms" so that hit counts will be combined for linked synonyms. This would be useful, for example, in a genre classification task where the class names "R&B" and "RnB" are equivalent.

jWebMiner also allows user-definable "filter strings." This permits the software to be set to ignore all web pages that do not contain general filter terms such as "music," for example, or application-specific terms such as “genre” or “mood.” This can be useful in avoiding irrelevant and noisy hit counts. For instance, a feature extraction should not count co-occurrences of “The Doors” with “Metal” or “Rap” unless they refer to music rather than unrelated topics such as the building industry or door knockers.

It is also possible to set jWebMiner to limit searches to particular sites, such as the All Music Guide or Pitchfork, in order to emphasize musically relevant and reliable sites. jWebMiner also allows users to assign varying weights to particular sites as well as to the web as a whole when feature values are calculated.

The feature values generated by jWebMiner essentially consist of relative similarities measured between various specified search strings, after appropriate statistical processing. These feature values can be exported to ACE XML, Weka ARFF, delimited text or HTML files. Feature values may also be browsed directly via the GUI.

3. MINING LAST.FM WITH JWEBMINER 2.0

The most significant improvement incorporated into the new jWebMiner 2.0, in addition to the existing functionality described in Section 2.4, is the ability to extract social tag-based information using the Last.fm API [19]. For example, users can specify artist names and have the software extract the most common tags for that artist from the Last.fm API, ranked by popularity. The user can also specify class labels of interest, and have jWebMiner derive features based on whether each artist has been tagged by Last.fm with any of these labels and, if so, have the feature value reflect the tag’s relative Last.fm ranking.

jWebMiner 2.0 can extract just the Last.fm-derived features, just the Yahoo!-derived features or both. If the latter option is selected, then jWebMiner will not only extract each of the two feature sets individually, but will also provide the user with levels of support associated with each class label based on the normalized combination of the Last.fm-derived and Yahoo!-derived features. This normalization process is performed to level all queries to the same number-base in the case of the Yahoo!-mined features, and to represent the position of a given artist’s Last.fm tag on a normalized scale. For an artist and genre we define a scoring function $S(a,g)$, where $P(a,g)$ is the Last.fm position of the queried tag and $P(a,i)$ the position for all genre tags:

$$S(a,g) = \frac{1}{P(a,g)\sum_{i=1}^{n}\frac{1}{P(a,i)}} \quad (1)$$

To exemplify the normalization process let us query the german band *Tarwater* with the tags *indie, post-rock* and *electronic.* These tags appear respectively in the position 6, 7 and 1 of the top tags for that artist. Being n equals 3, the value of the sum is 1/6 + 1/7 + 1/1, which is 55/42. Thus, the scoring function values are 7/55 for *indie*, 6/55 for *post-rock,* and 42/55 for *electronica.*

jWebMiner automatically bases its score on only the Yahoo!-derived features if a particular artist is not on Last.fm, or if an artist has not been tagged with any of the queried class names. In addition, jWebMiner can show the web search normalized feature score, the Last.fm normalized ranking score, and the averaged results. These values can be processed independently afterwards.

It is hoped that the combination of social tag-based feature extraction with more general web search-based feature extraction will provide MIR researchers with a unified and accessible cultural feature extraction tool that provides access to two different kinds of valuable cultural musical information available on-line. Although jWebMiner 2.0 can certainly be used alone, it also carries the significant advantage of allowing features extracted with it to be easily processed using jMIR’s ACE machine learning tool, or combined with features extracted from audio or MIDI by, respectively, jMIR’s jAudio and jSymbolic feature extractors [13].

4. EXPERIMENTS

4.1 Overview

A series of experiments were performed in order to investigate the relative performance of features derived from Last.fm social tags, features derived from Yahoo! web searches and the combination of features derived from both sources. Attention was also given to various possible web search feature extraction configurations, involving the use of various different filter words and site weightings (see Section 2.4).

The feature groups and extraction configurations were evaluated based on their performance in genre classification. As noted in Section 1, genre classification was chosen because it can be a particularly difficult task, and is thus a good stress test for features.

All experiments were performed using jWebMiner 2.0, which harvested features using the Last.fm and Yahoo! web services, as described above.

4.2 Dataset used

The experiments were conducted using the SAC (Symbolic, Audio and Cultural) dataset [13]. This dataset consists of 250 matching MIDI files and audio recordings, as well as accompanying metadata (e.g., title, artist, etc.). This metadata was stored in an iTunes XML file, which was parsed by jWebMiner in order to extract cultural features from the web [13].

The files of the SAC dataset are divided into 10 different genres with equal numbers of artists per genre (*Modern Blues, Traditional Blues, Baroque, Romantic, Bebop, Swing, Hardcore Rap, Pop Rap, Alternative Rock* and *Metal*). It is clear upon observation that these 10 genres consist of 5 pairs of similar genres. This arrangement makes it possible to perform 5-class genre classification experiments as well as 10-class experiments on the same dataset simply by combining each pair of related genres into one class. An additional advantage is that it becomes possible to measure an indication of how serious misclassification errors are in 10-class experiments by examining how many misclassifications are in an instance's partner genre rather than one of the other 8 genres. The ground truth was created using expert sources, such as AllMusic.com, combined with the personal expertise of the authors of the dataset.

SAC was chosen partly because it provides two tiers of genre classification; partly because the similarity of each of the 5 genre pairs makes 10-class classification particularly difficult, and thus a good test of jWebMiner's effectiveness; and partly because it can be used in other research to investigate the utility of combing the cultural features extracted by jWebMiner with other kinds of features, such as features extracted from audio, symbolic and lyrical data. This latter application was previously investigated with jWebMiner 1.0 in [13], and an update to this research using jWebMiner 2.0 is presented in [15] .

4.3 Text filtering and site weighting

In order to optimize classification accuracy using jWebMiner's filtering capabilities, we designed and tested several sample filters for the *Required Filter Words* and *Excluded Filter Words* fields. Sources such as [2], [4], [7], and [17] have recommended certain required filter words, such as *music*, *review*, *like*, *work* and *artist* x *played* y *music*, and have also recommended certain excluded filter words, such as *mp3*, *download*, *videos*, *cart*, *prices* and *login*. In general, our results matched those obtained in [7], which is to say that better performance was achieved when only simple filters were used. Thus, only *mp3* and *store* were used as excluded filter words, and no required filter words were used. It was found through informal experimentation that too much noise was otherwise introduced by web pages in which many of these terms co-occur with in non-specific ways with many other artists and genres.

We also developed a set of synonyms for different genres and artist names in order to take into account the variety that one finds in practice. So, for example, we used the terms *Bebop* and *Be-bop* as synonyms for *Bop*. On the other hand, an artist such as *Derek and the Dominos* could be found as *Derek and the Dominoes.*

We also tested different site weighting schemes. To begin with, we tried simply querying the whole network (NC, as described in Table 1) using the 5-genre taxonomy. We then queried the web as a whole as well as three predetermined websites (*wikipedia.org*, *allmusic.com* and *amazon.com*), using weight values of 0.5 for the whole network and 0.166 for each one of the sites (*W1*). For 10-genre classification, we tried a third arrangement that did not take into account the whole network, and where each of the above three sites was assigned a weight of 0.333 (*W2*). Experiments with these these different arrangements were performed in order to gain insights into how data mined from the web as a whole performed relative to specialized websites.

MK08	Previous experiment with jWebMiner performed in [13].
NC	No constraints involving weighting, required filter words or excluded filter words.
F/W1	*MP3* and *store* as excluded filter words. Site weightings of 1/6 for *wikipedia.org, allmusic.com, and amazon.com; the whole web weighted by 1/2.*
F/W1/S	Same settings as F/W1, plus a set of synonyms for the genres and artist names.
ST	Classification results when using only social tags.
C NC	Combined and averaged results using web search with no constraints, as well as social tags.
C F/W1	Combined and averaged results using social tags and web search in F/W1 configuration.
C F/W2	Combined and averaged results of social tags and web search, *MP3* and *store* as excluded filter words, and site weightings of 1/3 for *wikipedia.org, allmusic.com, and amazon.com.*

Table 1. The different configurations tested on the SAC dataset. Some experiments involved 5-genre classification, while others involved 10-genre classification.

4.4 Results

4.4.1 SAC dataset 5-genre classification

Table 1 provides brief descriptions of each experimental setup, as well as specifications of the identifying notation used. The average classification accuracy rates for experiments involving only web search-based 5-genre classification are shown in Table 2.

MK08	NC	F/W1	F/W1/S	ST	C F/W1
87.2	82.4	90.1	93.1	95.4	96.9

Table 2. Average classification accuracy rates for 5-genre classification experiments on the SAC dataset.

It can be seen that the *NC* experiment classification accuracy was worse than *MK08*, which is not surprising because the *MK08* experiments used some filtering constraints, namely the use of "music" as a required filter word. However, with the *F/W1* and *F/W1/S* configurations we observed improvements of 2.9% and 5.2% over *MK08*, and 7.7% and 10.7% over *NC,* respectively. These results suggest that highlighting particular music-related sites can provide better results than simply extracting information from the web as a whole.

On the other hand, retrieving social tags alone resulted in improvements in genre classification performance of

8.2% over the *MK08* mark, and the combined approach of retrieving social tags as well as querying the web resulted in the highest classification rate of 96.9%. Hence, it appears that combining the features from web searches and social tags can increase accuracy and diminish the problems associated with each method, such as noisy web search hits (as reviewed in [13] and [6]) and the *cold start*, *polysemy*, *annotation accuracy*, *popularity bias*, and *malicious behaviour* issues associated with social tags (as reviewed in [8] and [14]).

4.4.2 SAC dataset 10-subgenre classification

For 10-genre classification, we performed the same experiments but separated synonyms, filter words and site weights in order to gain insights on how each one of them affect results. The same SAC genre-pair weighting scheme used in [13] and described in Section 4.2 was also used to evaluate the seriousness of those classification errors that did occur Specifically, if a misclassification is within a genre pair, the error is reduced to 0.5 of an error, and if the misclassification is outside of a pair, then the error is increased to 1.5. Table 3 shows the weighted (W) and unweighted (*UW*) Yahoo! web search-only accuracy rates that we found.

	MK08	NC	F/W1/S	F/W1	F/W2	ST
UW	61.2	56.5	50.4	67.2	77.9	43.5
W	67.4	63.7	51.9	76.7	82.8	43.9

Table 3. Classification accuracy rates in 10-genre classification experiments, including both unweighted (*UW*) and weighted (*W*) results.

As in the 5-genre experiments, *NC* performed worse than *MK08*. On the other hand, *F/W1* and especially *F/W2* were more accurate than *MK08* by 6.0% and 16.7% respectively in terms of unweighted classification accuracy, and by 9.3% and 15.4% respectively in terms of weighted classification accuracy. Also, in the 5-genre classification experiments social tags gave excellent results. In contrast, in the 10-genre classification experiments using social tags (*ST*) social tags actually performed the worst amongst all configurations.

To understand this phenomenon, we studied the tags that Last.fm users use and found that, in general, they are very well defined for broad genres, such as those used in the 5-genre experiment. However, when one delves into finer classification, there are many subtle differences in the ways that different people perceive genres. For example, how substantially different is the genre *Rock* from *Punk* if we think of a band such as *Green Day*? In addition, a number of problems related to tagging such as polysemy, synonymy, accuracy, and spam are present in large collections of social tags [8]. Furthermore, tags do not represent only genres or styles, but anything that individual users want, from *mood* to *BPM*, so they can be very noisy if one wishes to extract detailed class labels.

To overcome these problems, we tried combining the features extracted from both Last.fm social tags and Yahoo! web searches. The obtained results are shown in Table 4.

	C NC	C F/W1	C F/W2
UW	75.6	74.8	77.9
W	78.6	79.8	81.3

Table 4. Classification accuracy rates for 10-genre classification experiments using combined data from both web search and social tags, unweighted and weighted.

It can be seen that for the *C NC* experiment, the combined data results in improvements of 19.1% (*UW*) and 14.9% (*W*) relative to using only web searches without any constraints. For the *C F/W1* experiment, the results were 7.6% (*UW*) and 3.1% (*W*) better. The genre classification accuracy was thus improved by using the combined approach, despite the fact that social tags alone performed very poorly. However, for the last experiment *C F/W2*, the results were the same for the *W* scale (as *F/W2)*, and slightly worse in the case of the *UW* scale. These last results make some sense because the *F/W2* experiment weights only the three predetermined websites mentioned above, rather than querying the whole web.

5. CONCLUSIONS

We have provided jWebMiner with new functionality, namely the ability to extract features based on Last.fm social tags. These features can be used alone or combined with jWebMiner's already existing Yahoo! search-based features, and the feature values can be summarized and saved in convenient formats for machine learning processing in future research.

We also performed web search experiments on different sets of excluded filter words and site weightings, in order to investigate their effect on genre classification accuracy. The experiments were performed on the SAC ground truth dataset, and improvements of 5.9% and 16.7% were achieved respectively for 5- and 10-genre classification compared to the results from earlier published experiments [13].

When performing the same experiments using social tags, we achieved an improvement of 8.2% for the 5-genre taxonomy, but also observed a 17.7% decrease in performance with the 10-genre taxonomy. It was thus found that social tags performed very well for broad genres, but lacked sufficient precision for more detailed sub-genre classes. However, the best results overall were achieved when both social tags and the web search data were combined. We conclude that the information obtained by each approach is at least partially, complementary.

In summary, the genre classification results obtained using both Last.fm social tags and Yahoo! web search-co-occurences were the highest observed amongst all configurations experimented with. Indeed, this combined approach actually achieved results comparable to those found in [13], where symbolic and audio data were also available and more sophisticated machine learning-based classification methodologies were used. The combined approach described in this paper was also extremely successful in a just-published followup to the [13] experiments, as described in [15].

6. FUTURE RESEARCH

Although the music classification results obtained in our experiments with jWebMiner 2.0 are very promising, we believe that there is still more space for improvement in accuracy. First, in order to properly filter music tags used by contributors to social sites, we will work on the development of a thesaurus of terms that can group together related words, something that should result in more precise tag rankings. Secondly, we will develop software for customizing web search site weightings through the automated application of genetic algorithms. A third research step will be to explicitly experiment with other types of classification, such as mood classification. Finally, efforts will be made to take advantage of any open-source web services in order to reduce the dependency on the excellent but proprietary Last.fm and Yahoo! services.

7. REFERENCES

[1] Aucouturier, J.-J., and F. Pachet. 2003. Representing musical genre: A state of the art. *Journal of New Music Research*. 32 (1): 83–93.

[2] Baumann, S., and O. Hummel. 2003. Using cultural metadata for artist recommendations. *Proceedings of the Third International Conference on Web Delivering of Music*. 138–41.

[3] Casey, M.A., R. Veltkamp, M. Goto, M. Rhodes, C. Rhodes, and M. Slaney. 2008. Content-based music information retrieval: current directions and future challenges. *Proceedings of the IEEE*. 96 (4): 668–96.

[4] Geleijnse, G., and J. Korst. 2006. Learning effective surface text patterns for information extraction. *Proceedings of the EACL Workshop on Adaptative Text Extraction and Mining*. 1–8.

[5] Geleijnse, G., M. Schedl, and P. Knees. 2007. The quest for ground truth in musical artist tagging in the social web era. *Proceedings of the 8th International Conference on Music Information Retrieval*. 525–30.

[6] Knees, P., E. Pampalk, and G. Widmer. 2004. Artist classification with web-based data. *Proceedings of the 5th International Conference on Music Information Retrieval*. 517–24.

[7] Knees, P., M. Schedl, and T. Pohle. 2008. A deeper look into web-based classification of music artists. *Proceedings of the 2nd Workshop on Learning the Semantics of Audio Signals*. 31–44.

[8] Lamere, P. 2008. Social tagging and music information retrieval. *Journal of New Music Research*. 37 (2): 101–14.

[9] Levy, M., and M. Sandler. 2007. A semantic space for music derived from social tags. *Proceedings of the 8th International Conference on Music Information Retrieval*. 411–6.

[10] Levy, M., and M. Sandler. 2009. Music information retrieval using social tags and audio. *IEEE Transactions on Multimedia.* 11 (3): 383–95.

[11] McKay, C., and I. Fujinaga. 2006. Musical genre classification: Is it worth pursuing and how can it be improved? *Proceedings of the 7th International Conference on Music Information Retrieval.* 101–6.

[12] McKay, C., and I. Fujinaga. 2007. jWebMiner: a web-based feature extractor. *Proceedings of the 8th International Conference on Music Information Retrieval*. 113–4.

[13] McKay, C., and I. Fujinaga. 2008. Combining features extracted from audio, symbolic and cultural sources. *Proceedings of the 9th International Conference on Music Information Retrieval*. 597–602.

[14] McKay, C., and I. Fujinaga. 2009. jMIR: Tools for automatic music classification. *Proceedings of the International Computer Music Conference*. 65–8.

[15] McKay, C., J. A. Burgoyne, J. Hockman, J. Smith, G. Vigliensoni, and I. Fujinaga. 2010. Evaluating the genre classification performance of lyrical features relative to audio, symbolic and cultural features. Accepted for publication at the *Int. Society for Music Information Retrieval Conference.* Utrecht, Netherlands.

[16] Turnbull, D., L. Barrington, and G. Lanckriet. 2008. Five approaches to collecting tags for music. *Proceedings of the 9th International Conference on Music Information Retrieval*. 225–30.

[17] Whitman, B., and S. Lawrence. 2002. Inferring descriptions and similarity for music from community metadata. *Proceedings of the 2002 International Computer Music Conference*. 591–8.

[18] Zadel, M., and I. Fujinaga. 2004. Web services for music information retrieval. *Proceedings of 5th International Conference on Music Information Retrieval*. 478–83.

[19] Last.fm Web Services. Retrieved 19 March 2010, from http://www.last.fm/api.

[20] Yahoo! Developer Network. Retrieved 19 March 2010, from http://developer.yahoo.com.