VIRTUAL CONDUCTOR FOR STRING QUARTET PRACTICE

R. Baez, A.M. Barbancho, A. Rosa-Pujazón, I. Barbancho, L.J. Tardón
Dpt. Ingeniería de Comunicaciones, E.T.S.I. Telecomunicación,
Universidad de Málaga, Campus de Teatinos s/n, 29071 Málaga, Spain
abp@ic.uma.es, ibp@ic.uma.es, alejandror@uma.es, lorenzo@ic.uma.es

ABSTRACT

This paper presents a system that emulates an ensemble conductor for string quartets. This application has been developed as a support tool for individual and group practice, so that users of any age range can use it to further hone their skills, both for regular musicians and students alike. The virtual conductor designed can offer similar indications to those given by a real ensemble conductor to potential users regarding beat times, dynamics, etc. The application developed allows the user to rehearse his/her performance without the need of having an actual conductor present, and also gives access to additional tools to further support the learning/practice process, such as a tuner or a melody evaluator. The system developed also allows for both solo practice and group practice. A set of tests were conducted to check the usefulness of the application as a practice support tool. A group of musicians from the Chamber Orchestra of Málaga including an ensemble conductor tested the system, and reported to have found it a very useful tool within an educational environment and that it helps to address the lack of this kind of educational tools in a self-learning environment.

1. INTRODUCTION

In recent years, our society has experienced a vast development of information and communication technologies as well as its integration in our everyday life. This phenomena has also spread to schools and educational models. Thus, for example, the use of internet has become an important asset in the classroom environment [1], as well as learning how to find a particular type of information among the different web resources as well as discriminating useful knowledge from redundant data. Furthermore, students are active users of many of the current Web 2.0 applications and emerging technologies, such as Facebook, Twitter and social networks in general, wikis, blogs, etc., and while the use of these resources in the classroom has not been yet consolidated, there is an intent and general agreement that the use of such tools could improve the learning process for the students, improving learning outcomes and/or creativity in the student [2], [3], [4], [5].

However, when it comes to the field of music studies, this array of tools might prove to be partially lacking. Of course, it is possible to make use of conventional web resources as a way to increase students' motivation towards learning, thus lowering potential barriers in regards to the abstract nature of music theory concepts. But music is a subject that relies heavily on practising and puts a special focus on interacting with other musicians to play complex pieces. With regards to this, the most conventional interaction paradigms and web 2.0 resources might prove to be insufficient, therefore requiring the use of more specialized tools and applications to provide a more specific interface for an adequate learning experience.

Looking into the research performed by the community in the field of human-computer interfaces for music interaction, there is a wide range of potential application fields and interaction models: virtual musical instrument creation/simulation [6], gaming and serious gaming [7], [8], [9], body-motion-to-sound mapping [10], [11], [12], guitar chords and frets detection [13], [14], singing voice interaction [15], tangible and haptic instrument simulation [16], [17], virtual drumkit emulation and drum-hitting simulation [18], [19], [20], etc. Particularly, with regards to orchestra conducting, there are a handful of systems and applications proposed that capture the conductor's gesture to control parameters of a virtual orchestra, such as tempo [21], [22], [23], [24] as well as dynamics [25], [26].

It is clear then that current technologies allow for the implementation of practice-oriented applications. Yet, from the perspective of a support tool for learning, most of these systems show some shortcomings that make them a less feasible solution. In extent, some of this interfaces are too exclusively focus on offering a recreational experience that can hardly be translated into a learning framework, and especially most of the examples cited require the use of very specialized hardware, thus limiting the potential target audience that can benefit from their use. Therefore, there is a need for more learning-oriented and accessible applications that can be used by students as a way to further improve their skills. Also, there is a lack of applications that make use of these technologies as a learning tool or to address concrete issues regarding musical practice.

In the case of string quartet groups, one problem typically found with regards to practising is that it can be difficult to coordinate all five members of the quartet for a given practice session. This can be specially critical if the conductor is not present, for in this case the rest of the musicians find it much more difficult to synchronize their

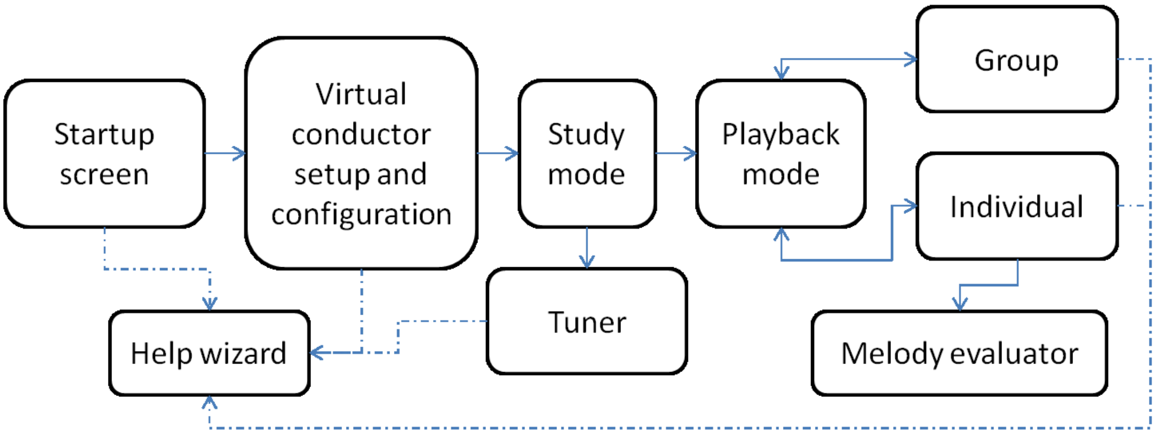

Figure 1. Modules of the Virtual Director application.

performances properly. This can ultimately make the value of the practice session diminish greatly. Thus, it would be quite useful to have a computer application that could provide beat and dynamics indications similar to those given by a real-life conductor. In this paper, we present an application developed to fulfil such purpose. In particular, this application implements a virtual orchestra conductor simulator for string quartet practice. Concretely, the system allows a musician to practise his/her performance either individually or in a group, and assess and evaluates the user's performance. In the next section, the details of the implementation of this virtual conductor will be covered, and later, the results of the tests performed will be briefly presented and discussed.

2. DESCRIPTION OF THE VIRTUAL CONDUCTOR SYSTEM

This application will emulate the role of a virtual conductor so that a musician can practise his performance as part of a string quartet ensemble. The application will assume a string quartet ensemble of four different instruments: violin, viola, cello and contrabass; however, the system can be configured to a different set of instruments, such as the more typical distribution of 2 violins, 1 viola and 1 cello. The system gives indications to the user regarding the beat times, changes in tempo, etc. The system also offers feedback to the user regarding his/her performance, evaluating the accuracy of the student when playing the corresponding piece. The application stores the information of each of melodies considered in MIDI format, and also allows for the playback of the MIDI data, so that the user can hear the piece as a whole for a better reference.

In this section, the general structure of the virtual conductor implemented will be presented, as well as the details of the components which the application consists of. A drawing of the different modules can be found in Fig. 1. The application will start with a presentation screen and then prompt a configuration menu to setup the virtual conductor parameters desired for the intended practice session. The system allows for two different study and playback modes, depending on whether the user wishes to perform solo or group practice. The application includes also a tuner module to ensure that the instruments are properly tuned before starting the practice session, as well as a melody evaluator that gives the user feedback on how accurate is his/her performance. A set of help menus are also provided to assist musicians in the use of the application.

The most relevant functionalities of the system will be described in the following subsections. In particular, the most important blocks in the application are the tuner, the melody evaluator and the virtual conductor emulation itself.

2.1 Tuner

When playing an instrument, it is extremely important to ensure that the notes played by the instruments are the ones that should be, in extent, that the instrument is properly tuned. In the case of string instruments, such as the violin or the viola, the musician must typically rely on his hearing acuteness and a tuning fork. To address this issue, the application includes a tuner module to assist the user in this procedure.

The music signal is recorded by a microphone, and then its spectrum is calculated with a sample frequency of 88200 Hz (thus allowing for a spectral resolution of 0.5 Hz). The tuner module was implemented following a similar detection method to the one presented in [27], analysing the spectrum of the signal recorded, and subsequently extracting the fundamental and partial frequencies. In order to do so, the peaks in the spectrum are detected by finding its local optima (using a window of 5 samples to the left and right of each potential peak candidate).

After that, a threshold value (set at a 20% of the maximum amplitude value found) is set to prune undesired peaks in the spectrum, following an iterative process: the sample with the highest magnitude is found, the 4 adjacent samples are erased (to account for the slopes of the peak), and a new iteration begins. Once the spectrum has been simplified this way, the distances between each successive peak $d(n_i, n_{i+1})$ are calculated and stored. In the standard frequency domain, the fundamentals and partials of a note would be found equally spaced along the spectrum, in frequencies f_{pitch}, $2f_{pitch}$, $3f_{pitch}$, $4f_{pitch}$ etc. Following this schema, it is possible to detect the fundamental

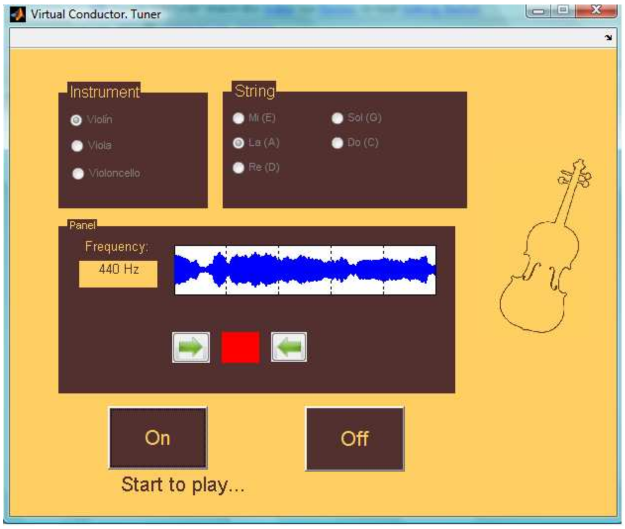

Figure 2. Tuner module interface.

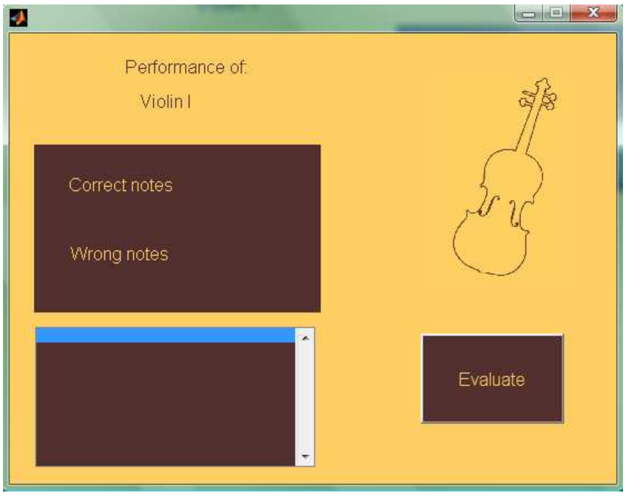

Figure 3. Melody evaluator dialog.

and partial frequencies, thus effectively extracting the pitch of the note played. The system then evaluates each peak detected to determine whether it belongs to fundamental-partials set or not. If the system finds either the fundamental frequency and at least 2 partials, or, alternatively, 3 partials or more, then it proceeds to assess whether the string is tuned or not. If the fundamental frequency of the note detected is within 2.2 Hz of the expected value, it is assumed that the corresponding string is tuned. Otherwise, the string must be tuned accordingly.

Depending on the type of instrument that the musician is playing (violin, viola, contrabass or cello) and the string being tuned, the system indicates the user whether the string is properly tuned (by turning a red button into green) or if it is necessary to either tune up or down the string played (by lighting the corresponding arrow), as can be seen in Fig. 2.

2.2 Melody evaluator

The purpose of this module is to analyse the piece played by the user, extracting the melody from the signal sampled and checking whether the student is playing the right notes or not. In order to perform this analysis, the audio signal is windowed so that each window holds the audio samples corresponding to each of the beats given by the virtual conductor.

The system knows beforehand which notes should play at each beat/bar from the data stored in the MIDI files. Thus, for each beat in the time signature, the system checks the MIDI data to identify the notes that should be played at that particular beat. For each window, the application uses the same detection method as for the tuner to find the fundamental frequencies, and compares them to the ones that should be had according to the notes assigned to that beat.

It may be possible that a time delay were introduced in the processing stage of the signal, therefore creating a potential desynchronization in the alignment of the MIDI score and the actual performance of the user. To account for this lack of synchronization, the system not only checks for each note in the corresponding beat window, but also in both the previous and next window.

Once the candidate notes have been detected, the system then evaluates if the notes played are the ones expected or if the user has made a mistake in his/her performance. For each note detected, it is assumed to be “correct” if the difference between the fundamental frequencies of the note detected and the expected one is lower to the minimum difference between the lowest note for the instrument considered and its sharp version. For example, in the case of the violin, the lowest note available is G3, and the difference between G3 and G#3 is 11 Hz. Thus, if a given detected note is within 11 Hz of the note expected for the time beat evaluated, the system labels it as a correct note, or as a mistake otherwise.

For each melody evaluated, the system indicates the user the amount of correctly played notes, as well as the number of notes which the user played wrong, and the corresponding beat times in the score. The dialog in the final application can be seen at Fig. 3).

2.3 Virtual Conductor

The main functionality of the system implemented is that of emulating the indications that an ensemble conductor gives to his/her fellow musicians when practising and playing a given piece. In order to implement this functionality, the system uses a virtual baton, represented by a set of four circles displayed on the computer screen. These circles change their colour and shape according to the beat and dynamics of piece played and the indication of the user in the configuration step. Each of the circles is placed in each of the four positions of the hands/baton that are typically used to signal beat times (up, down, left and right). At each beat time, the corresponding circle is coloured. The circles are coloured as if seen from the point of view of the musician, i.e. a 3/4 time signature would be signalled in the order down-right-up. The colour and size of each circle changes with the dynamics of the beat. Thus, for a *piano* or *pianissimo* nuance, there is a small light-coloured circle, while for a *mezzoforte-forte* intensity, the circle becomes larger and darker (see Fig. 4).

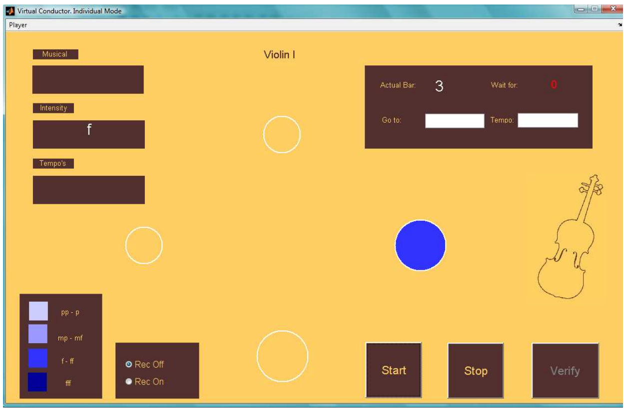

Figure 4. Virtual conductor for solo practice.

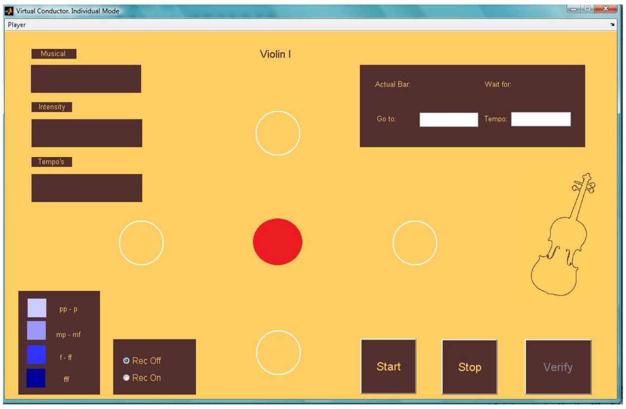

Figure 5. Indication of a *fermata*.

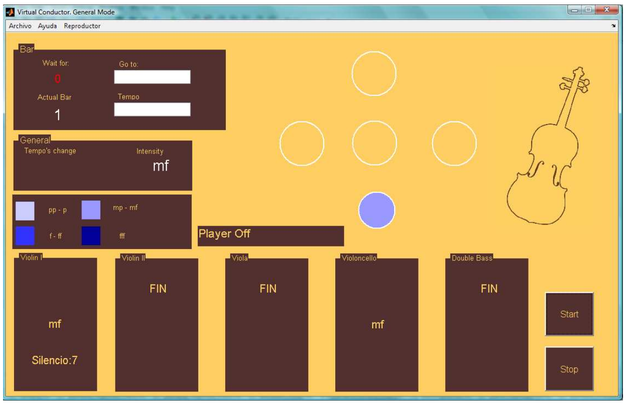

Figure 6. Virtual conductor for group practice.

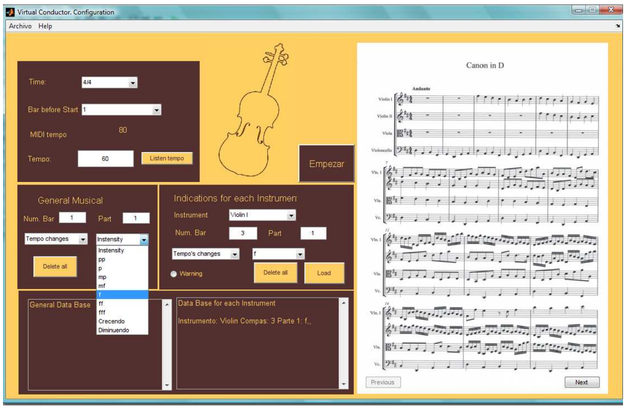

Figure 7. Configuration options with on-screen score.

In addition to the virtual baton, the application also gives additional visual feedback to the user to further guide his performance. In particular, dynamics nuances are also indicated in written form under the label “Intensity”, as well as additional dynamics indications (such as *ritardando* or *fermata*) under the the label “Tempo”; in the case of indicating a *fermata*, this is further signalled to the user by painting a red circle in the center of the baton (as per Fig. 5). Furthermore, there might and will be bars in a piece where a given instrument is not played at all; such indications are given under the label “Musical”.

The current bar number is also provided for further reference for the user. The user can also stop the performance at any time, restart at any given bar number, and manually change the tempo on the fly. This last option has been provided to specifically account for the fact that the tempo in rehearsals is usually initially lower to the actual tempo of the piece, and it is slowly increased as the musicians practise further.

The virtual conductor can be used for solo practice or group practice. In the case of the latter, the information provided by the system differs slightly from the previously commented features. Concretely, the space devoted to the virtual baton on the screen is more confined, and the indications given refer to the general indications that affect every single instrument globally. For specific indications for each of the instruments taking part in the performance, a set of panels are provided (first and second violin, viola, cello and contrabass) as seen in Fig. 6

2.4 Other modules

The virtual director tools has been design so that it can be fully configured to the needs of the student as well as providing an intuitive and easy to use interface. In that regard, the application also includes several modules and options to offer a more satisfying and complete experience to the user, such as a help menu, the possibility of loading music scores for reference on the screen, setting the tempo and speed nuances (*ritardando*, *fermata*, *crescendo*, *diminuendo* ect.), indicate a specific bar, an *anacrusis*, etc. An example of the configuration screen can be seen at Fig. 7

3. RESULTS AND DISCUSSION

3.1 Tuner

We conducted a set of tests to verify the correctness of the tuner implemented. In order to do so, we had access to a set of string instruments, and tuned them using the tuner module developed. Since the frequency of the notes for each string in a properly tuned instrument is known, checking the validity of the tuner application is immediate once the frequency peaks (fundamentals and partials) are extracted.

For the violin, it was found that the fundamental frequency for the G3 note could not be detected, but the string could still be tuned by detecting the first partial. The same result was obtained for the C3 note in the case of the viola. In the case of the cello, the fundamental frequency for the C2 note could not be found, nor could the first partial, but the note being played could still be detected by looking at the second partial. For all the other cases, the fundamental frequency of the note played was always detected, and thus it was possible to tune each string accordingly.

3.2 Melody evaluator

In order to test the viability of the melody evaluator implemented, we conducted a simple experiment in which a musician played a short piece, and the system gives a ratio of successfully played notes. For the tests, we used a set of melodies from pieces for the different string instruments considered (violin, viola, cello and contrabass).

The results yielded showed that the success rate oscillated between 100% and 84%, depending on the melody played and instrument used, with the best results found in the case of the cello (100% success rate with all the melodies), and the worst results (84% success rate) was found in the case of both the viola and the violin when playing Pachabel's Canon.

After analysing the spectrum of the melody played, it was found that the errors found in all cases were caused because of a lack of proper tuning of the instruments. For example, in the case of Pachabel's Canon for the violin, the error notes were F3 (739 Hz) and C3 (554 Hz); the fundamental peaks were not detected themselves, but the first partials detected for each note were at 1468 Hz and 1111.5 Hz respectively, while it should have been 1478 Hz and 1108 Hz had the instrument been properly tuned. After tuning all the instruments considered and repeating the tests with the same pieces, it was found that the melody evaluator had now a ratio of successfully detected notes of 100% in all cases.

3.3 Virtual conductor

To assess the effectiveness of the virtual conductor system as a learning tool, we presented the application to a set of musicians from the Chamber Orchestra of Málaga, as well to an ensemble conductor. Each participant learned how to use the application and was asked a total of 6 questions which they had to answer with a value ranging from 0 to 10, being the former the score given if they found no real utility to the tool, and the latter the one in case they found it extremely useful. The questions in particular were:

1. How useful did you found the tool developed?
2. Was the program easy to use?
3. Would you use this tool in your practice?
4. Do you find the tool useful as a way to enhance learning processes?
5. Are the indications given by the virtual conductor clear enough?
6. Please, state your personal opinion.

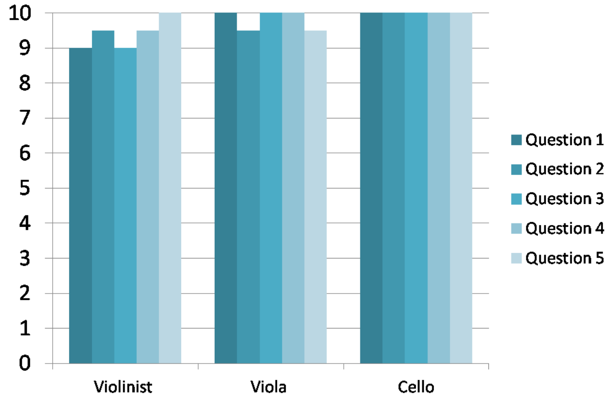

Figure 8. Virtual Conductor assessment from users' questionnaire.

The answers collected were overwhelmingly positive, with the average scores for all the items in the questionnaire being between 9 and 10. The average scores for each of the 5 questions are summarized in Fig. 8, in different sets according to the instrument played by the musicians that took part in the study. In their personal opinions, the participants also indicated that they found the tool especially useful both for solo and group practice, and that it would be desirable that there were more similar commercial products available, for it covers an important aspect with regards to music learning that is lacking in current paradigm.

The system was also tested by a professional ensemble conductor, who found the virtual conductor proposed to be an excellent pedagogical tool for musicians at any learning stage, as it addresses one important handicap in the learning process, which is solo rehearsing of chamber pieces. Furthermore, she found particularly enticing the group practice possibilities of the application, for it makes the learning process less lonely as well as it gives the student a much better context for his/her performance.

4. CONCLUSIONS AND FUTURE WORKS

In this paper we have presented the work conducted towards the development of a support tool for music learning that emulates the role of an ensemble conductor. The system does not only give indications similar to the ones given by a real-life conductor, but it also provides additional functionalities that further enhance or ease the learning experience, such as built-in tuner or a melody evaluator. To further validate the usefulness of the application developed, a set of experiments were conducted. The fellow musicians who tested the proposed system deemed it to be a really useful tool for the purposes of music learning, and highly encouraged that similar devices were available in the future, as there is a need for such kind of support tools that is not currently covered with the currently available resources.

While the response of the participants was quite positive, we would like to further improved the discussed tool in future iterations by integrating additional functionalities. The system can also be extended to account for a wider range of instrument than that of string instruments (e.g. wind instruments). Adapting the system to make use of real WAV files instead of MIDI files for playback would increase the audio fidelity of the system, providing more realistic sounds. The interface might be improved further with the addition of additional (such as changes over time on arousal and valence) as well as with the implementation of a more refined presentation of the cues (like, for example, having a virtual 3D model of the director giving indications in a more continuous, realistic way).

Acknowledgments

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