Computer-Aided Analysis and Pedagogy: Algorithmic Harmony and Voice Leading

Rachel Mitchell
University of Texas – Rio Grande Valley

Harmonia App

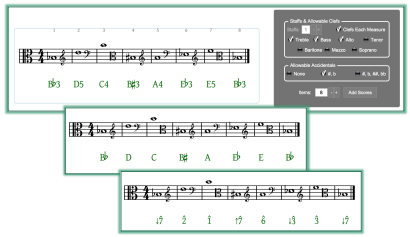
Harmonia is a music analysis software app that combines a music notation editor with a sophisticated algorithmic analytical engine that can assess multi-part, tonal music scores and parse them into harmonic chord structures and analyze contrapuntal motions and voice leading. The app analyzes music using essentially the same rules and guidelines we teach our students to gain a basic understanding of tonal musical practice. It can determine key areas and modulations, harmonic functions, diatonic and chromatic harmonies and non-harmonic tones, interval sizes and qualities, and find voice-leading errors such as parallel octaves, voice crossing, doubled leading tones, and more. The app contains as its in-app corpus the 371 harmonized chorales by J. S. Bach, which may also be searched for sonorities or voice-leading errors. (See Figures 2-5)

By combining such technology with a user-friendly, graphical interface, music scholars with even the most limited computer skills can easily navigate the app and use its analytical tools to conduct corpus-based studies such as those found in Tymoczko, Quinn, and White. Such technology also has applications in music pedagogy, whereby teachers can create interactive assignments resembling those found in any textbook or workbook and students can practice analysis and part-writing concepts and receive immediate computer-generated feedback. (See Figure 1, 6 & 7)

Harmonia was developed by Illiac Software, Inc. with support from the National Science Foundation and the University of Illinois. Harmonia is unique among educational music technology software in that students use the in-app text and notation editors to analyze/label melodies and harmonies and complete composition-based exercises such as pitch, scale, interval, and chord spelling assignments as well as more complex SATB chorale settings of diatonic and chromatic chord progressions, figured-bass realizations, and more. Figures 6-7 show sample Harmonia exercises and Harmonia-generated feedback.

Analytical Figures

Figure 1: pitch, pitch-class, and scale-degree generation and analysis



Analytical Figures

Figure 2: computer-generated analysis (roman numerals)
Harmonia analyzes voice leading: note the spacing error (m. 2, b. 4). Hover over the annotation to display an explanation (in yellow).

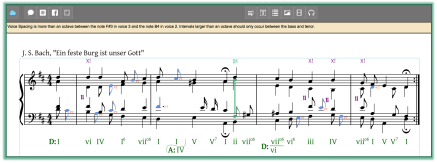


Figure 3: computer-generated analysis (harmonic functions)
Harmonia analyzes voice leading: note the voice crossing (m. 1, b. 1). Hover over the annotation to display an explanation (in purple).

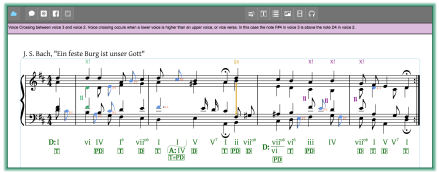
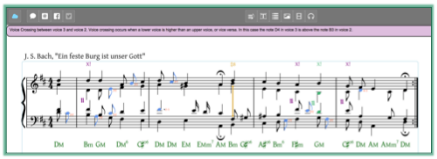


Figure 4: computer-generated analysis (figured bass)
Harmonia analyzes voice leading: note the voice crossing (m. 3, b. 3). Hover over the annotation to display an explanation (in purple).

Figure 5: computer-generated analysis (chord symbols)
Harmonia analyzes voice leading: note the voice crossing (m. 3, b. 4). Hover over the annotation to display an explanation (in purple).



Assessment Figures

Figure 6: sample Harmonia analysis exercise
Harmonia grades: click the red check mark at the upper right to submit and hover over a graded annotation to learn more about an error. Harmonia describes the error in m. 2 in the red dialogue box.

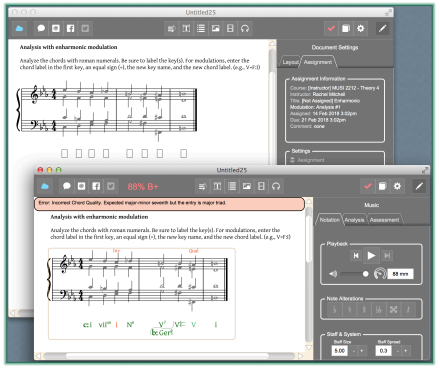
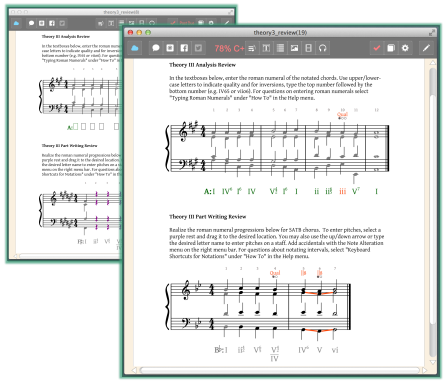


Figure 7: sample Harmonia analysis and part-writing exercises
Harmonia can randomize keys for part-writing exercises to provide multiple practice attempts for students. Note how one part-writing example is in F-sharp major, while the other is in B-flat major. Instructors can limit key randomization to a particular interval or to key signatures with a limited number of sharps or flats.

Observe the annotations in the graded submission. Multiple dots above a chord indicate multiple errors. Click on each to learn more.



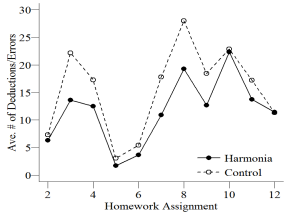
Procedure

In a 2015 NSF STTR application we proposed to complete the implementation of a prototype software called Harmonia and test its efficacy as a key instructional component in a college level music theory course. We used Music 101, which is the first semester of the two-year core music theory program for music students at the University of Illinois. Specifically, we designed and implemented:

1. A software module that converts the results of our patented automatic analysis algorithms (US Patent No. 4,754,489) into assignment *grading metadata* that is collected on a *cloud server* for aggregation and analysis.
2. A software module that turns grading and analysis results into graphical annotations and markup directly on students' music scores, as a direct analogue to how music teachers grade and mark-up paper assignments.
3. A software module that randomizes the choice of musical keys when displaying musical scores.
4. A semester's worth of automated music theory assignment and practice materials. Materials were completed inside Harmonia by one experimental group and on paper by a control group.
5. A plan to test the efficacy of the Harmonia beta application through a controlled classroom experiment comparing two populations of students in Music 101.

At the beginning of the fall 2015 semester, 53 University of Illinois Music 101 students elected to participate in the NSF study. 35 students used Harmonia exclusively for instruction and homework and one control group of 18 students used traditional paper-and-pencil instruction and homework assignments. Students' homework assignments in both the Harmonia and control groups were graded using the Harmonia 2.0 software, which catalogues the specific type of error (out of 40 possible errors) made on each item. The number of errors and deductions was computed for each student on homework assignments 2–12. Figure 8 plots the average number of errors made by students in the Harmonia and control groups across the 11 homework assignments.

Figure 8: average number of deductions and errors on homework assignments 2–12 for Harmonia and Control groups



Results

Figure 8 provides evidence that exposure to the Harmonia software reduced students' total number of errors. Using the Harmonia software reduced the number of errors students made by an average of 3.66 (s.e. = 1.82, $p < 0.05$) across the 11 assignments. Furthermore, Figure 8 shows that the effect of the Harmonia software was most pronounced for homework assignments 3, 4, 7, 8 and 9; follow-up moderator analyses suggested that Harmonia reduced the number of errors made on the aforementioned assignments by an average of 5.42 (s.e. = 1.65, $p < 0.01$).