Yaolong Ju

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ACADEMIC BACKGROUND

Education

- *Jilin University (JLU), Changchun, China* Sep. 2009 – July 2013
  B.S. in School of Computer Science and Technology
  Major: Computer Science and Technology
  Thesis: The Research of Automatic Arrangement (Honors)
  Advisor: Prof. Lan Huang
  GPA: 3.73/4.00

- *Peking University (PKU), Beijing, China* Sep. 2013 – July 2016
  M.S. (Recommended for Admission) in School of Electronics Engineering and Computer Science
  Major: Intelligence Science and Technology
  Research Interest: Automatic melody harmonization, key-finding and machine learning
  Thesis: Research on Automatic Chord Arrangement Based on Deep Recurrent Neural Networks
  Supervisor: Prof. Xihong Wu
  GPA: 3.62/4.00

- *McGill University, Montreal, Canada* Sep. 2016 – PRESENT
  Ph.D. in Schulich School of Music
  Major: Music Technology
  Research Interest: Automatic harmonic analysis, large-scale music datasets, machine learning
  Supervisor: Prof. Ichiro Fujinaga
  GPA: 3.90/4.00

Selected Awards & Honors

- National Grant Oct. 2010
- Self-reliance and Independence Student May 2011
- National Encouragement Scholarship 2010 – 2012
- School Outstanding Student 2010 – 2012
- Chinese Computer Federation Scholarship Oct. 2012
- Top 100 outstanding students of Chinese Computer Federation Oct. 2012
- Xianzi Zeng Educational Fund 2011 – 2013
  Jilin University

- Graduate Special Scholarship Oct. 2014
- Graduate Fellowship 2013 – 2015
  Peking University

- Interdisciplinary Research Project Seed Grant June 2017
  Granted by Centre for Social and Cultural Data Science (CSCDS), McGill University for my research proposal "Automatic Harmonic Analysis Using Deep Learning".
- Graduate Excellent Award Nov. 2016, Jan. 2018
- Annual Research Assistant Stipend 2016 – 2020

- CIRMMT Traveling Award July 2017, Mar. 2018

- CIRMMT Student Coordinator Sep. 2017 - Sep. 2019
  Assist with coordination of workshops for the research axis of music information research.

- CIRMMT Student Award Mar. 2018
  Traveling funding for my participation of international academic conferences. Awarded by Centre for Interdisciplinary Research in Music Media And Technology (CIRMMT) for my research proposal "Generating Multi-style Harmonic Analysis Using Artificial Intelligence for Homorhythmic Music".
- FRQSC Doctoral Scholarship 2018 – 2022
  Awarded by Fonds de recherche du Québec - Société et culture (FRQSC) for my research proposal "Generating Multi-style Harmonic Analysis Using Artificial Intelligence for Homorhythmic Music".

  McGill University

Publications

- Lan Huang, Shixian Du, Yu Zhang, **Yaolong Ju**, and Zhuo Li, "K-means Initial Clustering Center Optimal Algorithm Based on Kruskal," *Journal of Information and Computational Science*, Vol. 9, No.9, pp. 2387-2392, 2012.
- **Yaolong Ju**, Nathaniel Condit-Schultz, Claire Arthur and Ichiro Fujinaga, "Non-chord Tone Identification Using Deep Neural Networks" in *Proceedings of the 4th International Workshop on Digital Libraries for Musicology*, 2017.
- **Yaolong Ju**, Kate Helsen, "The LMLO goes MEI: An Exercise in Melodic Encoding Translation" in *Presented at the 6th Music Encoding Conference*, 2018.
- Nathaniel Condit-Schultz, **Yaolong Ju**, and Ichiro Fujinaga. A Flexible Approach to automated Harmonic Analysis: Multiple Annotations of Chorales by Bach and Praetorius. In *Proceedings of the 19th International Society for Music Information Retrieval Conference*, 2018. (Accepted)

Research Experience

Distributed Digital Music Archives & Library Laboratory, McGill University Ph.D. Candidate

- **Non-chord Tone Identification Using Deep Neural Networks**
  Advisor: Prof. Ichiro Fujinaga **April 2017 – PRESENT**
  This project addresses the problem of harmonic analysis by proposing a non-chord tone identification model using deep neural networks (DNN). By identifying non-chord tones, the task of harmonic analysis is much simplified. Trained and tested on a dataset of 140 Bach chorales, an initial DNN—using only the pitch-class content of individual sonorities as input—was able to identify non-chord tones with an F1 accuracy-measure of 57.00%. By adding metric information, a small contextual window around each input sonority, and fine-tuning the DNN parameters, the model's accuracy was increased to an F1-measure of 72.19%. These results suggest that DNNs offer an innovative and promising approach to tackling the problem of non-chord tone identification, and then harmonic analysis.

  This project was awarded the Centre for Social and Cultural Data Science Interdisciplinary Research Project Seed Grant from McGill University ($2,000 CAD), and has resulted in peer-reviewed publications. The promising results of these preliminary experiments serve as a solid foundation for my research of automatic harmonic analysis.
- **Extracting Searchable Musical Features for ELVIS database**
  Advisor: Prof. Cory McKay **July 2017 – PRESENT**
  The ELVIS Database[1] is a large symbolic music dataset containing 2,852 pieces and 3,358 movements by 164 composers. The abundance and diversity of symbolic music data make ELVIS an ideal resource for my harmonic analysis research. In this project, I use jSymbolic2[2] to extract various musical features (pitch statistics, melodic intervals, chords and vertical intervals, rhythm, instrumentation, texture, and dynamics[3]) for each symbolic file in ELVIS. These features will be added to the ELVIS database as metadata, allowing users to search, filter, or summarize the database based on these features—for instance, a user might search for pieces that contain a certain type of chord, or create a table of all chord types in a subset of the database.

[1] https://database.elvisproject.ca

[2] jSymbolic2 is a software application to extract statistical information from musical data stored symbolically in file formats such as MIDI or MEI.

[3] Specified in http://jmir.sourceforge.net/manuals/jSymbolic_manual/home.html

All the features of interest will be automatically extracted from any new music added to the database, making them immediately available for search and analysis.

This project has given me further technical experience managing the infrastructure of large-scale musical databases, including database extension, organization and the automation of database processing. This work will soon be submitted as a paper to International Symposium on Computer Music Multidisciplinary Research (CMMR) 2018.

- **Melodic Encoding Translation for Medieval Chants**
  Advisor: Prof. Kate Helson and Prof. Ichiro Fujinaga **June 2016 – June 2017**

  Andrew Hughes was an influential Canadian musicologist and a pioneer of digital musicology research. Hughes encoded the melodies and texts of nearly 6,000 medieval chants in a complex, idiosyncratic digital format. Unfortunately, this dataset was only stored on floppy discs, and no software for parsing the idiosyncratic encodings exists. Thus, as part of a digital Festschrift for the research legacy of Andrew Hughes, I have worked to extract this dataset, translate it to a more convenient modern encoding format, and make it accessible online.[4]

  Hughes' digital encodings were parsed and translated into the Music Encoding Initiative (MEI) digital format. Hughes' data, originally encoded in a single file, was divided into a more convenient, systematic file structure, with chants organized in "chant letter - saint - repertoire - office - chant" order. Pitch information in Hughes' encodings was encoded numerically based on the medieval church mode system, requiring a complex algorithm to translate it to a modern pitch representation. An online Latin syllabifier[5] was used to parse the text, but had to be modified to include information about liturgical words not found in other contexts, such as "Kyrie." During this stage, some errors in Hughes hand-typed data were isolated and resolved. The entirety of Hughes' chant collection has now been successfully transcribed into MEI and can be rendered as music notation in Verovio.[6]

  Through this project, I have obtained experience of parsing and processing symbolic music data, as well as creating and curating large-scale music datasets. This work is accepted as a proposal to the Music Encoding Conference 2018.

Key Laboratory of Machine Perception (Ministry of Education), Peking University Masters Student

- **Research on Automatic Chord Arrangement Based on Deep Recurrent Neural Networks**
  Advisor: Prof. Xihong Wu **Nov. 2013 – June 2016**

  This project, the topic of my master thesis, proposed an automatic chord arrangement (ACA) model based on various types of deep learning models. The project had three principle stages: First, a deep neural network hidden Markov model (DNN-HMM) was proposed—DNN replaces the distribution sequences in HMM to model the emission probability, allowing it to better learn mappings between melodies and chords. Second, the relationship between the choice of input unit and modeling accuracy was studied. Multi-state modeling of each chord in HMM was found to best preserve the original chord sequence information. Chord accuracy and chord distance were adopted as evaluation criteria. Experimental results show that the performance of DNN-HMM model was better than that of the HMM model, with a relative chord accuracy improvement of 1.61%, and a chord distance reduction of 10.9%. Third, since long-term dependencies between notes can be better captured by a recurrent neural network (RNN), a special form of RNN called Long-Short Term Memory (LSTM) was adopted. The performance of LSTM-HMM outperformed those of DNN-HMM and HMM, with a relative chord accuracy improvement of 2.04% and 3.68%, and a relative chord distance reduction of 3.48% and 14.0%, respectively.

  This project is an important antecedent to my current proposal—my long-term, ongoing engagement with the interdisciplinary application of computer science and music theory to chord arrangement has given me essential practical experience with the application of deep learning to harmonic analysis.

- **Survey of Symbolic Key-finding Algorithms**
  Advisor: Prof. Xihong Wu **May 2015 – June 2015**

  This project aimed to propose an automatic key-finding algorithm to complement our current automatic harmonization system. Most existing key finding methods are based on *key-profiles*: The frequency of each pitch in a piece is calculated and the distribution is correlated with known key-profiles—the profile with the highest correlation is considered the key. However, this method only considers the zeroth-order distribution of pitches; other, more detailed, melodic information is ignored. Therefore, we proposed a novel key-finding

[4] https://github.com/DDMAL/Andrew-Hughes-Chant/tree/develop/
[5] Available at: http://docs.cltk.org/en/latest/latin.html#sentence-tokenization
[6] http://www.verovio.org/mei-viewer.xhtml

system based on recurrent neural networks (RNN). Such a model can not only integrate more musical information (meter, duration, phrase and pitch spelling), it can also model long-term note dependencies.

The problem of key-finding is intertwined with that of harmonic analysis—to maximize its utility, my harmonic analysis software will ultimately be integrated with key-finding module.

- **Creating Music with Laptop Orchestra**
  Advisor: Prof. Ge Wang **June 2014 – July 2014**
  This three-week seminar, organized by the Stanford Center at Peking University offered me the opportunity to work with CCRMA students from Stanford University using laptops and corresponding controllers to create music. During this seminar, ChucK, a programming language for real-time sound synthesis and music creation, was introduced alongside simple tutorials about music instrument design, sound synthesis, and group live performances. In the end, all participants were asked to perform in a concert. With the help of ChucK, my own original composition was encoded digitally and segmented into several segments which could be triggered in real-time by a controller. The controller was also programmed to alter the volume and vibrato of the timbre.

  This seminar broadened my horizons and gave me hands-on experience with new topics (instrument design, gesture control of music performances, and sound synthesis) related to interdisciplinary computer-science / music research.

Laboratory of Computational Intelligence, Jilin University Undergraduate Student

- **Research of Automatic Arrangement**
  Advisor: Prof. Lan Huang **Feb. 2013- May 2013**
  This project, the topic of my undergraduate thesis, focused on creating an automatic system which can arrange chords for a given melody and generate idiomatic musical accompaniments with three possible instruments (piano, electric guitar, and electric bass). The system is modeled on a similar system called Mysong, which was developed by Microsoft. The system used hidden Markov models (HMM) for chord arrangement while the accompaniment texture for each instrument was defined manually through a rule-based system. The system's automated accompaniments, in most cases, match the input melodies well. This work also used hidden semi-Markov Model (HSMM) to improve the system by explicitly modeling the duration of chords—this modified system created significantly better chord arrangements.

  In this project I discovered my principle research passion: the application of machine learning to musical harmony. All my training and development since, right through my masters and doctoral studies, has been building the interdisciplinary skills and knowledge necessary to pursue the research of automatic harmonic analysis.