Judges' Commentary: The Influence of Music

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Introduction

Music influence is a topic that many people discuss but often know little about. For this year's Interdisciplinary Contest in Modeling (ICM®) problem involving network science (or operations research), the goal was to use network and data modeling from several data files to model and measure the influence of artists on one another and determine other factors that affect artists, genres, and songs. The problem also asked teams to investigate evolutionary and revolutionary trends of bands and genres. The data sets included:

- `influence_data` provided musical influencers and followers for 93,064 musicians over the last 60 years, including both self-reports by the band members and as reported by industry experts.

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- `full_music_data` provided 15 characteristics of musical features (such as danceability, tempo, loudness, key) on over 160,000 songs. These data also formed three smaller summary data sets, including:
  - mean values by artist `data_by_artist`,
  - means across genres `data_by_genres`, and
  - means across years `data_by_year`.

The problem asked teams to confine their work to these data only. ICM teams were asked to:

- Create a directed network(s) of musical influence, where influencers are connected to their followers.
- Develop measures that capture music influence in this network.
- Develop measures of artist similarity to explore similarity versus influence among artists.
- Identify whether some musical features are more contagious than others.
- Find features that might indicate major leaps (revolutions) in musical evolution. If so, what bands could be considered influencers or revolutionaries?
- Identify the dynamic influencers in one genre and explain how the genre developed over time—who were the main influences, what period of time did the music show dramatic changes, what other social, political, or technological changes were occurring at that time that may have contributed to the evolution of the music.
- Explain how their modeling approach of the network of musicians improve our understanding of the major influences of music in a one-page document to the ICM society.

Both the triage and the final judges considered how a team:

- created meaningful measures of influence and similarity;
- used these measures to identify influencers and understand the evolution of artists and genres of music over six decades;
- captured the dynamics of music, how they identified evolution and revolution, and how they considered historical events that impacted music; and
- interpreted their results, identified weaknesses in their models and the data, and suggested ways to improve.

Discussions of Outstanding Papers

To address the problems, teams all started by creating an influence network from the data provided, where artists are nodes and where directed "influence links" were formed from influencers to followers. Teams presented rank-order lists of influential artists using the various measures that they created. The teams also created similarity measures using the musical characteristics of songs, which they used to compare artists and genres to determine influences among artists. Successful teams also established subnetworks of artists by genre to apply their measures. Eight papers were rated as Outstanding by a panel of 11 final judges. Summary reports for the eight outstanding papers follow.

Beijing Normal University, "Music Influence and Evolution Analysis Based on Networks"

Like many teams, the team from Beijing Normal University first restated the problem and commented on the strategies that they would follow to answer specific questions. Additionally, the team presented the workflow of their paper using an informative graph. Then the team presented the assumptions on which they based their analysis. In answering the problem's questions, they first drew a directed network of the influencers, followed by the use of network measures such as degree centrality, weighted degree centrality, and eigencentrality. They also produced a comprehensive score (F-score) that considered all these three measures. Although this was a network science problem, not many papers used clear network science measures in a well-defined way; this paper did a good job in that regard. The team chose a few subnetworks based on their F-score, which they used to answer the rest of the problem's suggested questions.

To measure similarity, this team used Euclidean distance. This was one of the good types of measures that were used in many other papers. In combination with this measure, they applied the Mann-Whitney statistic to compare similarities between and within genres. The team assumed that the main differences between genres are differences between their characteristics. To measure these differences, they created a Genre Classification Tree and looked at the relative position of the features in the tree. The team then produced a directed network of genres, where the relation among genres is measured by the music influence among their characteristics (see **Figure 1**). The team continued with the construction of a similarity Bayesian network to study whether influencers indeed influenced their followers. To address this question, the team focused on one band (the Beatles) and their followers and found that the characteristics of Beatles' music equally affected the music of their followers.

The team also discussed revolutions in music. They connected a revolu-

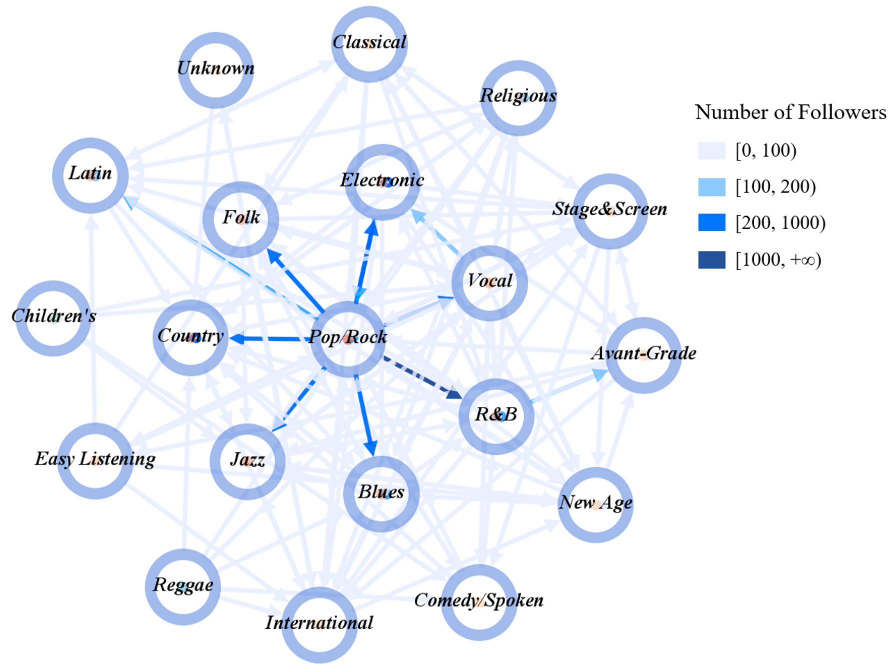


Figure 1. Genre network from Beijing Normal University.

tion with how the number of influencers of different genres changed, and they analyzed how music characteristics of genres varied over time. To this end, they applied a dynamic programming algorithm and found which of the music characteristics are related to musical revolutions. They built another similarity Bayesian network for the artists of two genres, to explain how one genre (Pop/Rock) was reinvented and spurred the creation of a new genre (Electronic). Further, the team worked on including time in their model and creating an indicator of dynamic influencers, which led to the 10 most important dynamic influencers in Pop/Rock. The team also identified in the data three main periods of musical evolution and discussed social, political, and technological factors that could explain these types of music evolution. Then the team did a sensitivity analysis, finding that their model was robust to change. The team concluded with the strengths and weaknesses of their analysis.

The document to the ICM Society addressed the requested points of discussion. The team explained the value of their models, how additional data could be used, and suggested further questions to answer. However, the team could have done an even better job of discussing why using network-science measures was appropriate or valuable to solve the specific problem. Similarly, the team could have explained, in more detail, how their results would improve with additional data. Nonetheless, this document was one of the most complete ones in the contest.

Overall, the team from Beijing Normal University is designated as Outstanding, because the team not only answered the problem's prompts, but they also wrote clearly. They presented their ideas using well-posed arguments and explaining the reasons behind their modeling decisions. The team included the basic elements of good modeling (assumptions, sensitivity analysis, strengths and weaknesses) and used a strong network-science approach. They also included well-constructed graphs, pictures, and tables that contributed to the reader's understanding.

Fudan University, "Measures of Influence and Similarity in Dynamical Networks of Musicians" (AMS Award)

This paper started out with a standard PageRank algorithm. The team recognized that earlier artists may be weighted higher, due to there being more subsequent artists to follow them. Therefore, they modified the PageRank by weighting the rank by a factor that takes into account differences in the relative position with respect to their contemporaries. They showed graphics of the changes of the graph over time, but it would have been interesting to see the dynamic detail of top artists according to their algorithm.

To calculate the similarity of artists, they created a weighted cosine measure between the angle of the feature vector. The weights were calculated to match the minimum hop count between the nodes in the graph and solved numerically using a stochastic gradient-descent algorithm. This technique has the disadvantage of losing the magnitude information, which is likely important in this situation. The derived similarity between artists was used to modify the weights in the graph to emphasize links where there is more similarity, and then the PageRank algorithm was run again. Comparisons to the unweighted PageRank algorithm were made. These rankings were also used to develop an overall influence measure of a genre. Three examples provided in the paper were Jazz, which had both influence and number of artists reduced over time; Rock, which shows increases; and Electronic has a spike in the 1990s.

The algorithm that this team used to look for revolutions in the music started by plotting the different features over time. They identified that energy and valence dropped during turbulent years (world wars and financial crisis). Acousticness goes down with new technology; but the team noted that classical and vocal music are less affected, as would be expected. The duration of songs has decreased as attention span has decreased; the Blues genre is used as an example. The team analyzed the network, influence, popularity, and number of artists over time. In addition, they analyzed the change in the characteristics vector over time. They tested these results using a graph convolution (machine learning) network. A small amount of training data was selected, and then the rest of the data were processed. The neural network was able to correctly identify about 55% of Rock artists, but the accuracy went down as the number of artists in a category went down, possibly due to too little training data. This was an interesting analysis, but it would have been more interesting to have the details of the approach.

The summary letter included not just a rehash of the algorithms, but a discussion of the data and what other data would be helpful for further analysis and how the analysis in the 2000s is hampered by lack of data. Although the algorithms in this paper were fairly standard (PageRank and cosine similarity, for instance), the team elevated their analysis to earn an Outstanding rating.

University of Electronic Science and Technology of China, "How to Analyze the Music Objectively?" (Leonhard Euler Award)

This paper is strong in many respects. The team's analysis explored meaningful aspects of musical evolution using several complementary approaches, making effective use of the data alongside the modeling problem itself. What made this paper Outstanding is that the authors were able to give a clear contextual interpretation to each of their analyses, which were often quite technically sophisticated.

The effectiveness of this approach was highlighted in the team's analysis of revolutionary artists, for which they used a version of closeness centrality defined for directed networks and depicted in **Figure 2**.

Already this is quite sophisticated; few teams employed network analysis to address aspects of the later, richer questions posed within the modeling problem. More importantly, the team's interpretation of in- and out-closeness computed on the artist-influence network was succinct and discussed in the list of assumptions: "revolutionary artists are the ones who have a large impact on others while receiving small influence from others." This approach gave results so clear that they almost speak for themselves.

The paper begins with a description of the network of influence among artists, which likely helped the team to make sense of the network. They used simple, effective normalization to summarize influence across time and between genres, but did not discuss it much. As many teams did, they based their definition of influence around out-degree. The modifications they made to give a "weight" to the links were intriguing, but there was discussion among the judges whether this would improve the network.

The authors' analysis of musical characteristics incorporated an understanding of the modeling problem as a whole, just like the analysis of revolutionary artists. Many teams viewed genres as collections of artists and focused on the distance between distributions of pairwise similarities among artists. This team explained their approach clearly, even as they used highly-sophisticated statistical analysis. They also took uncommonly great care in aggregating up from artist to genre. When discussing similarities and differences across all genres, the paper used a representative vector

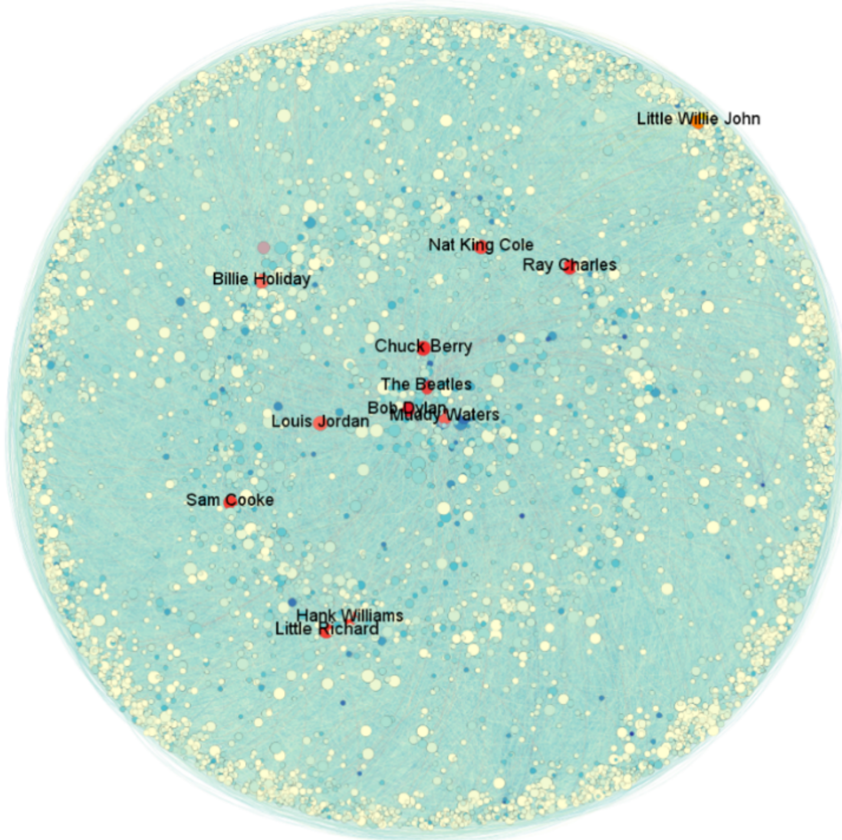


Figure 2. The synthesized closeness centrality of the top 12 artists, from University of Electronic Science and Technology of China.

of musical characteristics, defined as a weighted average of the artists from that genre, giving a higher weight to influential artists whose followers are similar to them. This made the findings multifaceted.

Our enjoyment of music is, of course, a subjective experience; and this year's Problem D really highlights how there is no single right answer in mathematical modeling. This observation leads us to an aspect of this paper that could be improved. The paper places substantial emphasis on the "objectivity" of the analysis and on the mathematical tools themselves. First, it is not at all clear that objectivity is possible or desirable in the context of music. As is always the case, the team's findings reflected the data that they had been given and their subjective interpretation of the modeling problem. More important to their success was that they made their take on the questions very clear and selected a set of mathematical tools that they could nicely interpret in the context of music history. The team could have produced a stronger one-page letter to the ICM Society by recognizing that it is the interpretability of their mathematical model, not its sophistication, that contributes the most to their goal of bettering our understanding of the subject.

Shanghai Jiao Tong University, "Mining the Influence of Music based on Social Network Analysis and Statistical Methods" (INFORMS Award)

This submission impressed the judges as being clearly written and well organized. After a restatement of the problem, this team built a directed network to measure musical influencers, follower loyalty, and differences between an influencer genre and a follower's genre. The focus then shifted to analysis of similarities in music, concentrating on a number of features, including danceability, tempo, valence, and more. In this section, the team used factor analysis to view these features as a linear combination of the variables associated with the various features. This was a method that the judges felt enhanced the analysis and was reinforced with clear illustrations to visualize the data.

When discussing the development of new genres of music, the team showed that the creation of genres is not an isolated event, thus creating a representation for this called "accumulated loyalty" to acknowledge how an artist in one genre can be influenced by artists in other genres. To discuss and identify extremes, the use of outlier detection was implemented and described using violin plots—a good technique that impressed the judges. The use of time-series models to discuss the process of genre evolution over time played a large factor in awarding this paper the INFORMS Award. This work resulted in data showing that vocal music flourished between 1920 and 1950 and Pop/Rock music has developed rapidly since 1960. Later, the team used the previous results from focusing on features in music to see how the features of each genre evolve, showing that the acoustic energy component of all genres has fluctuated over time, while the valence component has had an upward trend for all genres.

This team concentrated on the musical pioneers using Bollinger Bands and the First Order of Temporal Correlation Coefficient to close out their work. They uncovered that the Beatles and Nat King Cole were revolutionary pioneers. As stated in the strengths and weaknesses section of the paper, this paper created "comprehensive and reasonable measures," while also using the data-driven methodology of the entropy-weighted method.

Xidian University, "How Does Musical Influence Lead to Musical Revolution?"

This paper showed excellent exposition of modeling the music influence problem. It impressed judges with its clear and concise writing and organization. The paper is easy to read and understand, with a thoughtful discussion of methods and results. In addition to the clarity of the writing, the paper stood out in its modeling approaches. The authors used commonly applied techniques for measuring influence and similarity in music but then elevated these methods by creating new measures.

The executive summary clearly stated the methods used to create and analyze a music influence network, investigate the similarities in musical genres, and identify times of musical evolution and revolution. The summary also gave a brief overview of the results of the models. This key piece of information was often missing from executive summaries of other papers. Since the executive summary is the first thing read (and perhaps the only thing in professional settings), it is important to have a stand-alone summary that sparks the curiosity of the readers and encourages them to read further.

Using the data provided, the authors successfully created a directed network and used standard network science measures such as degree centrality, eigenvector centrality, and PageRank to identify influencers. These metrics were utilized by many teams, but this paper thoughtfully explained each and created a "Musical Influence" metric using a combination of these common measures. The authors also made an attempt to validate the results by comparing their findings to a media report. A degree distribution of the influence network was provided and analyzed. The authors determined that the network data follow a power-law distribution and included a discussion of the implications of this structure. Few papers did these extra steps to analyze the network structure and attempt to validate their model results.

The paper continued by creating several subnetworks to examine in more depth the cross-genre, intra-genre, and predecessor-junior influence. These subnetworks were graphically illustrated in the paper, with the nodes sized based on their influence measure. The team's approach to identify music similarity was a common one taken by many teams, but again the authors improved it by combining Euclidean and cosine similarities with an additional local similarity where four music features were considered. These methods, along with the heat maps to compare the findings, were presented and explained. The team classified musicians by genre using principal component analysis, identified "mutation" points over time in the time scale of electronic music, and examined contagion of musical characteristics by two selected artists. Another strength of the paper was its unique approach to examining musical influence, where it considered different time scales in a sliding-window model. Few teams considered both short-term and long-term influence on followers.

Many excellent figures are included in the paper that help the reader to understand the modeling steps (e.g., a flowchart highlighting the techniques used in the modeling), model explanations, and analysis of the results. These graphs demonstrated the paper's efforts to explain the results. For example, the team provided a helpful graphic to demonstrate its "Sliding Window" model, shown in **Figure 3**.

In the conclusion of the paper, the team included sensitivity analyses on the size of their sliding window parameter and a parameter in their music similarity calculation. Strengths and weaknesses of the report were briefly

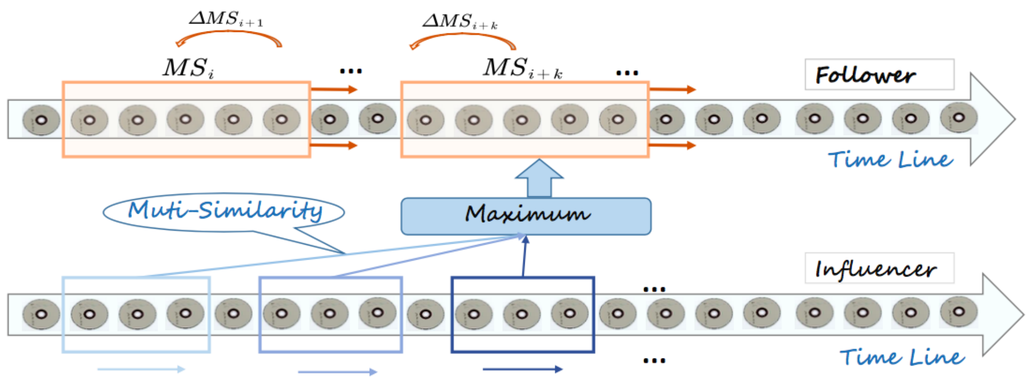


Figure 3. Graphic from the Xidian University paper to show the details of their sliding window algorithm.

addressed as well. The team's memo to the ICM Society is a thoughtful summary of the work, with specific details of what additional data would be needed and how it could benefit the existing model.

Overall, this paper presents many interesting results and clearly shows the hard work of the authors. There are many levels to analyze in this data and problem from the artists to the genres to considering time and this team successfully addressed each.

China Agricultural University, "An Exploration of Music Evolution Based on Influencer Network and Cosine Similarity"

This paper impressed the judges as an outstanding example of interdisciplinary modeling and problem solving, analysis, and communication that provides a concise, logical, and insightful answer to the challenges of the problem. The team started with a brief problem restatement, summarized their background research with appropriate references, and then articulated their approach in a straightforward manner. They provided pertinent and justified assumptions prior to describing a directed influencer network model. Initially, the team's approach did not differ significantly from others; but then they creatively introduced a unique cooling effect (borrowed from physics) to enrich their musical influence model. Cosine similarity between eigenvectors representing artists or genres formed the basis for an innovative musical influence model, which included a decay factor. The judges agreed that the number of follower artists and duration are interesting because both are important aspects of "influence." At the same time, the appropriateness of this specific modeling approach provided opportunities for further exploration.

The team created a straightforward similarity measure for artists within genres and between genres, which they illustrated with skill and explained clearly. The judges appreciated the team's use of figures to communicate ideas visually, particularly similarity density curves in **Figure 4**, to help understand the data presented.

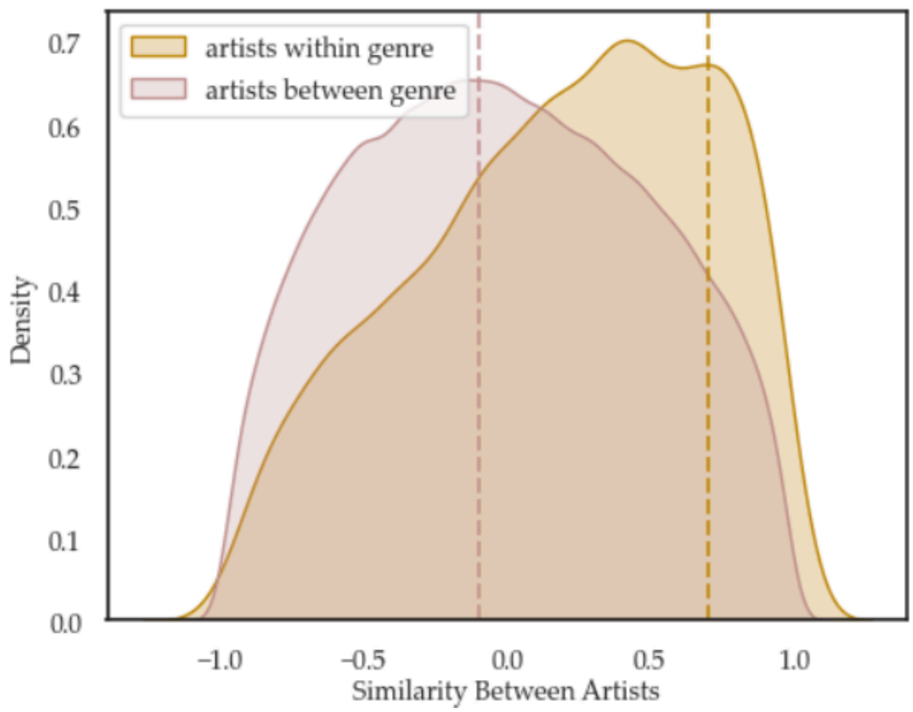


Figure 4. The density curve of similarities between followers and influencers, from China Agricultural University.

Using selected principal factors, the team investigated the relationships among artists to produce a powerful solution. The team's work concisely addressed the abstract question of which music characteristics might be considered "contagious." Using four factors, the team demonstrated the possibility to distinguish between genres and make comparisons using music data. The team then employed a gravitational model to identify the dominant genre for each year. Although these results were inconclusive, this approach demonstrated depth in model exploration.

Discussion about the fusion and branching of genres caught the judges' attention as particularly interesting work. Using their basic model, the team successfully included year-by-year similarity analysis that sought characteristic signals to identify observable revolutions in music that might relate to historical events (although cosine similarity may or may not be the most appropriate similarity measure). The paper's discussion about sensitivity analysis, model strengths, and model weaknesses provided opportunities for future work.

Although the one-page explanatory document to the Interdisciplinary Contest in Modeling (ICM) Society summarized the team's approach very well, the judges noted that there could be more description about the value of the team's approach to understanding musical influence using networks. Additionally, the judges were curious to know more about how the team's work would change with additional (or richer) data to better understand the team's recommendations for further study of music's cultural effects.

The College of William & Mary, ”Sonic and Iconic: Music Revolutions from Sound-Based Genres” (SIAM Award, MAA Award, COMAP Scholarship Award)

This paper impressed judges for its novel approaches to modeling, a well-written narrative describing the model choices and iterative improvements made to the models that the team developed, and the use of out-of-sample testing to validate their model choices. Like many other teams, their work started by measuring the influence of artists by forming an unweighted directed network based on influencer data. Instead of developing one overall measure of influence, the authors chose to decompose influence into four components: direct influence on the entire network of artists, indirect influence on the network, direct influence within the artists' genre, and influence across genres. This approach allows for a more nuanced analysis of the types of influence a particular artist had, while still allowing for combining the four components into one measure of overall influence.

Another interesting model choice made by the authors was to develop a method for classifying artists based only on the sonic variables, as an alternative to using the established, predefined genres to classify an artist's music, and then including these algorithmically-developed ”sonic genres” in other analysis and models throughout their submission. These sonic genres were established using k-means clustering on the sonic variables and resulted in the four sonic genres summarized in the paper as **Table 1**.

Table 1.
Four sonic genres with artists, from The College of William & Mary.

Sonic Genre Name	Notable Artists
“Here Comes the Sun” Genre	The Beatles, Hank Williams, Bob Dylan
“Thunderstruck” Genre	AC/DC, Jimi Hendrix, David Bowie
“I Will Survive” Genre	Destiny's Child, Sting, Sia
“Swan Lake” Genre	Chet Baker, Dave Brubeck, Howard Shore

They also gave the coordinates of the centroids of each sonic genre, shown in **Table 2**, which give the reader a glimpse into the relationships among the sonic variables and newly-established sonic genres.

The sonic genres were used to update the team's previous work on artist influence by adding an additional component to their artist influence vector that measures the direct influence of the artist within their sonic genre. Sonic genres were also used in conjunction with established genres during the rest of the submission, as the authors studied similarity measures, contagiousness of sonic variables, and musical revolutions.

The writing style was effective and engaging. The team outlined their initial attempts at modeling and discussed their drawbacks before describing the adaptations that they made and the improvements that resulted.

Table 2.

Sonic Genre centroid data. Lowest values for each category are shaded in red (dark) while highest values are shaded in green (light).

	"Here Comes the Sun"	"Thunderstruck"	"I Will Survive"	"Swan Lake"
Danceability	0.524	0.531	0.56	0.399
Energy	0.422	0.725	0.626	0.31
Valence	0.536	0.57	0.544	0.313
Tempo	0.483	0.534	0.51	0.462
Loudness	0.682	0.778	0.749	0.566
Mode	1.0	1.0	0.0	0.861
Acousticness	0.605	0.134	0.254	0.694
Instrumental	0.056	0.096	0.141	0.73
Liveness	0.193	0.197	0.187	0.149
Speechiness	0.049	0.048	0.059	0.029

Reading the details of these modeling steps enabled the reader to gain a better understanding of the nuances in the data and finer details that needed to be considered during the modeling process. This paper also made good use of out-of-sample testing to validate the models built. This kind of validation is important for gaining confidence in novel approaches used in the analysis of an unfamiliar data set.

Northwestern Polytechnical University, "Music Never Gets Old: Study On The Development And Evolution Of Music"

As most teams did, this team built several network-based models and used a modified PageRank measure to calculate the influence of each node in the team's networks. This measure identified a rank order of influencers. The team's measure of similarity was based on the pairwise distance between characteristic vectors of artists' songs. Their results showed that most artists had a high similarity with artists in the same genre, although there were exceptions. The team used their measures of influence and similarity, along with heat maps and radar graphs, to describe music genres. By analyzing artists within a genre, the team obtained genre characteristics and tracked the evolutionary changes of the genres over time. Within their dynamic model, they identified the changing attributes of genres and discovered that some musical characteristics are more contagious than others and that music characteristics have different effects in different genres. Their results showed that Pop/Rock has similarities to Country, Blues, Reggae, and Latin, and that Pop/Rock was influenced by these other genres.

The team's analysis to find revolutionaries using song popularity led the team to conclude that the Beatles were the music revolutionaries of the 1960s. To analyze the evolution within a genre, they used popularity to determine if a song is contagious, and the vector of the characteristics of a genre's most popular song as the direction of that genre's music contagion. This time series gave the evolutionary flow of a genre. They reasoned that the stronger the inheriting degree of a musical characteristic, the less the musical characteristic changes with time. Therefore, a significant change in a musical characteristic that is normally stable is a significant indicator that a revolution had taken place. **Figure 5** shows some of their results of tracking five music charateristics with moderate inheriting degree: energy, tempo, acousticness, instrumentalness, and speechiness. From 1964 to 1969, acousticness dropped sharply, and energy rose during the period when the Beatles were the most active influencers. From these results, the team conjectured a law of genre change: The most popular music in a genre influences the entire genre and guides its evolution.

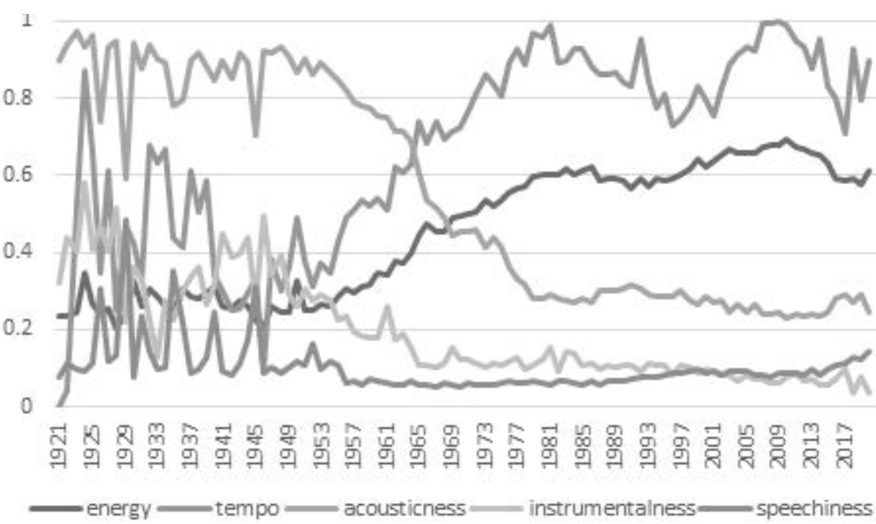


Figure 5. Graphs of average value of five characteristics of Rock/Pop by year, from Northwestern Polytechnical University.

The team's methodology to track the influence of culture and society events was likewise creative. When they analyzed the total popularity of the genres over each year, they noticed trends that could be caused by cultural and social issues. At the end of the Depression, the popularity curve showed an upward trend. During the Second World War, classical music suffered a setback and then recovered after the war with the improvement of society's economics. The American civil rights movement promoted the popularity of Blues. And as Moore's Law created affordable music technology, electronic music became more popular. In the Information Age, high-speed information flow boosted all genres' popularity. The judges noted that some of the labeled pictures in the report reflected the wrong year and were not located at the correct spot in the graph. Similarly, the discussion of the cultural and social effects of the civil rights and racial equality movements was vague and incomplete and could have been improved and expanded to reflect this important historical effect in music influence.

As thorough modelers, the team conducted a sensitivity analysis on the PageRank measure by varying the damping coefficient and on the similarity scores by varying the dimensions and elements of characteristics in the vector. The team listed their models' strengths as being creative in analyzing the evolution and revolution of music, and the judges agreed.

Conclusion

This problem presented opportunities and challenges to ICM teams to explore the evolution of music over six decades. Teams showed creative approaches to modeling networks, analyzing data, building measures, and investigating the cultural, social, and artistic elements of music influence. Almost all the ICM teams were able to build a viable network to quantify influence effects and created sensible measures to capture similarity of musical features. The Outstanding teams were able to use the data given to understand many different elements of musical artists, music genres, music characteristics, influencers, similarity in songs, popularity of musicians, evolution, revolutionaries in music, and were able to communicate their results effectively.

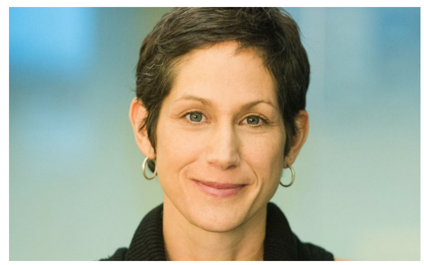
In general, judges preferred papers that were organized thematically by topic rather task-by-task (answering questions from the prompt like a series of homework problems). Strong papers present their models in a logical sequence, with the tasks woven in a cohesive manner. The prompts are suggested steps offered as a guide for teams, who should develop their own approach to the problem. The judges value creativity, innovation, soundness, and appropriateness of modeling approaches, as well as clarity in modeling and analysis decisions and interpretation of results. Imagine that your technical report is written for an audience of educated people with general interests in the topic of the problem. The presentation of results should appear as though it is a technical exploration of the topic rather than being motivated by specific tasks.

Another issue of concern is the choice of words and thoughts used in dealing with issues concerning human values, such as race, gender, sexual orientation, ethnicity, religion, politics, and social class. Modeling and measures must be value-based, and reports must be sensitive to explain analysis and results in these sensitive areas without prejudice or any form of discrimination.

The judges congratulate the members of the teams for their excellent work and dedication to interdisciplinary modeling, network science, data modeling, and problem solving. The judges were impressed by the ability of many teams to combine innovative modeling, data processing, and effective communication to address the elements of influence in music.

About the Authors

Chris Arney has a Ph.D. in mathematics from Rensselaer Polytechnic Institute. He graduated from the US Military Academy and served in the US Army for 30 years, including teaching mathematics and network science for 29 years at the Academy. He is the founding director of the ICM and served as the director of the contest for 21 years.



Kate Coronges is the Executive Director of the Network Science Institute at Northeastern University. She provides research and administrative leadership to the Institute. Her research focuses on social structures, dynamics of teams and communities, and the impact of these dynamics on communication patterns, behaviors, and performance. Previously, Dr. Coronges ran the US Army's research portfolios in Social and Cognitive Networks and in Social Informatics and served as an Assistant Professor in the Dept. of Behavioral Sciences and Leadership at the US Military Academy. Dr. Coronges received a Ph.D. in health behavior research and an M.P.H. from the University of Southern California. Her bachelor's degree from UC Santa Cruz is in molecular, cellular, and development biology. She was the head judge for the ICM Policy Problem for four years and in 2020 and 2021 served as the head judge for the ICM Network Science Problem.

Matt Geiser is a U.S. Navy logistician who currently serves as a program officer at the Naval Postgraduate School. He graduated from Ohio State University (B.S., architecture), Naval Nuclear Power School and Nuclear Power Training Unit, Navy Supply Corps School, and Naval Postgraduate School (M.S., operations research). His experience includes apprentice architect, submarine nuclear propulsion plant maintainer and operator, and military logistician serving throughout the U.S., Europe, Asia, and Pacific regions. He has been an ICM triage judge for three years.

Brian Macdonald is currently Special Faculty in Sports Analytics in the Dept. of Statistics and Data Science at Carnegie Mellon University. He was previously the Director of Sports Analytics in the Stats & Information Group at ESPN, Director of Hockey Analytics with the Florida Panthers Hockey Club, and an Associate Professor in the Dept. of Mathematical Sciences at the US Military Academy. He received a B.S. in electrical engineering from Lafayette College, Easton, PA, and a Master of Arts and a Ph.D. in mathematics from Johns Hopkins University, Baltimore, MD.

Carolina Mattsson is a postdoctoral researcher at the Dept. of Computer Science (LIACS) of Leiden University. She holds a Ph.D. in network science from Northeastern University, where she was an NSF Graduate Research Fellow. In her research, Carolina is developing network analysis tools and modeling frameworks needed to study the economy as a complex system.

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Candice Renee Price is an African-American mathematician and Associate Professor at Smith College in Northampton, MA. Born and raised in California, Candice has a bachelor's degree in mathematics from California State University, Chico, and a master's degree from San Francisco State University. She earned her doctoral degree in mathematics from the University of Iowa under Isabel Darcy. Her area of research is the application of mathematics to biology, primarily working in DNA topology, knot theory applied to the structure of DNA. She is an advocate for greater representation of women and people of color in the STEM fields.

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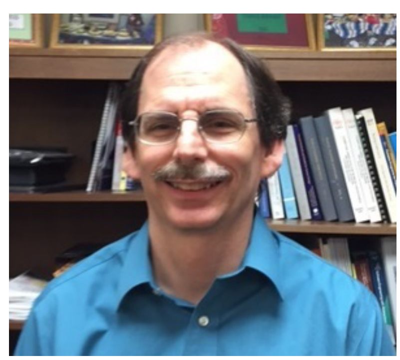

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