Quantune: An Automatic Music Generation Using Quantum Computing

Rahaman, Md Shahidur [1] **Islam, Agm** [2] **Orduz, Javier** [3 4]

Abstract

This study explores how quantum computing might revolutionize music. Given the rising demand in this field, we investigate applying quantum principles and functionality to offer developers and quantum computing experts new opportunities. We provide a complete performance evaluation using two different techniques to combine quantum superposition for pitch generation and the Basak-Miranda algorithm for rhythm generation. Ultimately, we demonstrate that backend code derived from quantum principles can successfully play back music by creating a web application. We envision a future where quantum computing expands the limitations of musical creation, stimulating innovation and pushing the boundaries of artistic expression.

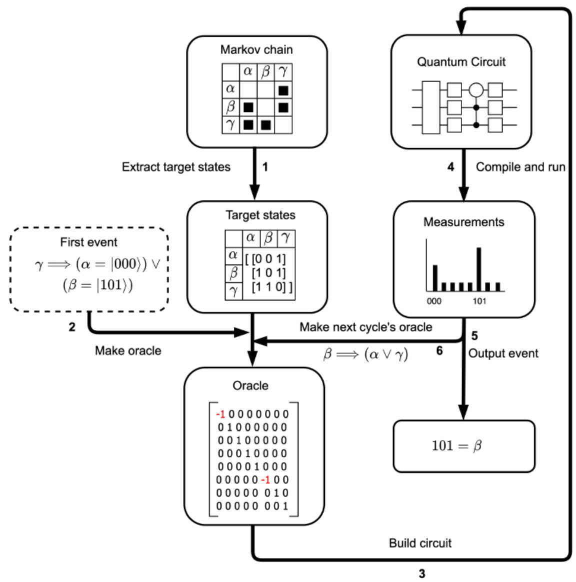

Figure 1. Steps in Bask-Miranda Implementation (Miranda & Bask, 2021)

1. Introduction

Music has always been a place for artistic expression, originality, and creativity (Ludwig, 1992). There is a continuing hunt for novel technology and methodologies that can push the frontiers of musical composition and performance as the need for fresh and distinctive musical experiences grows. With its capacity to use quantum mechanics and handle enormous amounts of information simultaneously, quantum computing offers a fascinating chance to thoroughly alter how we make and enjoy music (Polkinghorne, 2002). This research intends to shed light on the enormous potential of quantum computing in music, opening up new research directions for academics and music lovers. By imagining a time when cutting-edge technology and music are wholly integrated, we hope to push the boundaries of creativity and open up a universe of limitless opportunities. This revolutionary vision becomes a reality by utilizing the strength of quantum physics and its built-in parallel processing capability (Klco et al., 2022).

Our main goal is to investigate how quantum computing can be used in the creation and performance of music. We set out to research cutting-edge methods for pitch generation and rhythm generation in light of the burgeoning demand in this area and the game-changing opportunities that quantum computing presents to programmers and music lovers. Finally, we specifically seek to apply the Basak-Miranda algorithm (Miranda & Basak, 2022), a powerful tool for rhythm production, and quantum superposition, a fundamental concept of quantum mechanics.

Researchers have examined how simulation, computer logic, and musical composition connect. Hill's playback-based pitch identification tool (Doornbusch, 2004) pioneered using computers for music creation. With the creation of the ILLIAC computer, which could simulate a string quartet, Hiller et al. (Hiller & Isaacson, 1957) laid

[1] Department of Computer Science. Texas A&M University, Texas, USA [2] Department of Computer Science. Baylor University, Texas, USA [3] Department of Mathematics and Computer Science, Earlham College, 801 W National Rd, Richmond, IN 97141, USA [4] QMexico coordinator. https://qmexico.org/ Mex-USA. And Instructor online at BU. Correspondence to: Rahaman, Md Shahidur <mdshahidur_rahaman1@baylor.edu>, Islam, Agm <agm_islam1@baylor.edu>, Orduz, Javier <orduzja@earlham.edu>.

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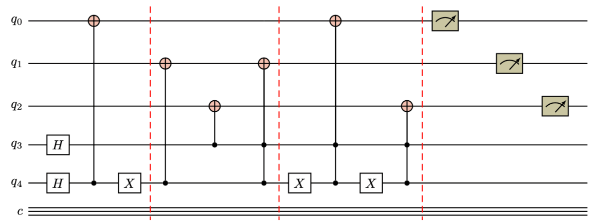

Figure 2. Implemented Quantum Circuit.

the groundwork for algorithmic music computation. The creation of jazz tunes over an input chord sequence was detailed by Papadopoulos et al. (Papadopoulos et al., 1998). They composed the music using a genetic algorithm. Similarly, Marques et al. (Marques et al., 2000) mention using fitness function, other melodic and lyrical theory notions, and genetic and evolutionary algorithms in large-dimension search spaces to produce musical sequences. Bretan et al. (Bretan et al., 2016) more recently presented a deep neural network method for automated music creation. These pieces serve as an example of the advancements made in using classical computing to compose music.

The works above demonstrate how computer modeling and logic have advanced music creation. While there have been considerable advances in classical computing, research into quantum computing's potential for music production is still in its early stages. This work, which focuses explicitly on pitch and rhythm generation, intends to close this gap by exploring the possibilities of quantum computing in music production. This study intends to add to the expanding body of knowledge at the nexus of quantum computing and music production by using quantum superposition and investigating the Basak-Miranda algorithm.

2. Methodology

We employed a rigorous and systematic approach involving pitch and rhythm generation to examine quantum computing's potential in music. Firstly, we utilized the quantum superposition principle to generate gradients, thereby enabling the simultaneous representation of multiple pitches. Moreover, to explore the innovative tonal possibilities of quantum computing, we devised a unique algorithm that leveraged quantum superposition to produce a wide range of pitches. Additionally, we used the renowned Basak-Miranda algorithm for rhythm production, which is known for its ability to create intricate and captivating rhythmic patterns. Furthermore, we aimed to investigate how applying quantum principles could enhance the rhythmic aspect of music creation by implementing this method within the quantum computing framework. Consequently, the Basak-Miranda algorithm was modified and optimized to harness quantum computing's parallel processing capabilities fully, thus facilitating the creation of complex and dynamic rhythm structures.

2.1. Basic Quantum Functionalities

For our implementation, we have used Qiskit Library (Olivieri et al., 2021), an open-source software development kit for developing quantum circuits. We need the following terminology: the qubit, a 2-D quantum system regarded as the rudimentary information carrier in modern quantum computers. The quantum register is where we can calculate and manipulate the n number of a qubit. We will then introduce the gates we used in our implementation. 1. **X-Gate:** We consider the first gate, the Pauli-X, which is the quantum counterpart of the NOT gate for classical computers concerning the standard basis, which determines the z-axis on the Bloch sphere (Boyer et al., 2017). 2. **Hadamard Gate:** One of the essential gates in quantum computing that shifts the Bloch sphere's poles and produces a superposition. 3. **CX Gate:** The CX Gate has a substantial effect on multi-qubit operations because it allows one gate to serve as a control and another as a target. 4. **CCX Gate:** This gate is called the Toffoli gate, incorporates a three-qubit operation, and is considered the reversible arrangement of AND gate. As we are dealing with five-qubits, we need to compute the merged states of our system. We calculate the tensor product($\otimes$) of two or more independent qubits to construct combinational states.

2.2. Algorithm Details

Our first interest in quantum computing was motivated by the random walk technique. The discrete interpretation of this procedure utilizes several qubits that incorporate a traditional random walk with Markov Chains (Yang et al., 2013) for each potential movement direction from a graph vertex. In addition, we can offer a set of twelve-tone notes for musical creation. A quantum-die then uses this music to accomplish the quantum walk in one dimension. For instance, we may operate the Markov chain probability distribution to discover the playing note shown in Table 1. The simulation phase selects the left note if the computed value is zero; otherwise, it determines the right note. A single qubit and a Hadamard gate will allow us to create the quantum die. A 1-D random walk responds nicely to this technique. However, this method will be ineffective when complicated rules are applied sequentially. As a result, we use the Basak-Miranda algorithm, the most recent method for the enhanced quantum walk algorithm (Miranda, 2021). Finally, the algorithm generated a matrix considering the sequence rule we obtained from the targeted state in the Markov probability distribution table.

$$\kappa = \begin{bmatrix} 1&0&0&0&0&1&0&1&1&1&0&0\\ 0&0&1&0&1&0&0&1&0&1&0&0\\ 1&0&0&0&0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&1&0&1&0&0\\ 0&0&0&0&1&0&1&0&0&0&1&0\\ 0&0&0&1&0&1&0&1&0&0&0&0\\ 0&0&1&0&0&0&1&1&0&0&0&1\\ 0&1&0&0&0&0&0&1&0&0&0&0\\ 0&0&0&1&1&0&1&0&0&1&0&0\\ 0&0&0&1&0&0&1&0&0&1&1&0\\ 1&0&0&0&1&0&0&1&0&1&0&0 \end{bmatrix} \tag{1}$$

Table 1. Markov Chain Sequence Rules

	A	F	C	G#	D#	F#	D#	G	E	C	E	A#
E	0.25							0.25	0.25	0.25		
D#			0.25		0.25			0.25		0.25		
C#	0.5								0.5			
G							0.33	0.33		0.33		
D					0.33		0.33				0.33	
F				0.33		0.33		0.33				
C			0.25				0.25	0.25				0.25
F#		.50						.50				
A				0.25	0.25		0.25			0.25		
G#				0.25			0.25			0.25	0.25	
A#	0.25				0.25			0.25		0.25		

Assume that the Markov chain implementation for note $C\#$ produced two states with equal probabilities. Now we generate a matrix called κ in equation (1). Taking the third row in the matrix, rule 3, the simulation will then proceed.

We can choose the one from the rule that matches the intended states represented by the qubits. We depicted the overall implementation of the method in figure 1. Taking into account the pitch we already took, the two qubits we obtain are for the states A and E, respectively, $|0\rangle_2$ and $|8\rangle_2$. Considering the next pitch in the simulation, we may infer from the matrix that the winner is $|3\rangle_4$. The histogram allows us to determine the state rapidly, and we will then use the same steps to complete the input tuning computation.

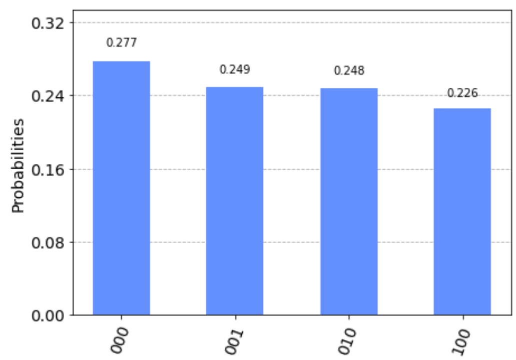

Figure 4. Histogram of rythm generation

3. Result

3.1. Implementation for Tune generation:

The algorithm stated before is adequately justified in five steps by our implementation. • **Circuit Creation:** We use a different approach called qwalk to create the circuit in the first stage, figure 2. We first specify the qubits, conventional bits, and quantum registers within that approach. Then, we consider the three conventional bits and the five qubits. Finally, we employ the Hadamard(H), Pauli X-gate(X), Controller-Not(CX), and Controlled-Controlled-Not methods using these (CCX). We honor from the gates that we created a multi-qubit procedure for our model. • **Transpilation:** We infer that developing the transpilation mechanism to repurpose our input circuit to mimic the structural design of a quantum device is the second stage of our approach. • **Note Generation:** Our circuit is repeated 100 times in the third phase to produce the note. Then, in 25 rounds, the histogram tracks the pitches that the simulation chose. We depicted the 100^{th} note production probability using a histogram in figure 3. • **Rhythm Generation:** The process of creating rhythms using the earlier-created technique comes next. Then, we execute the circuit method one hundred times to discover the beats. Finally, we construct the histogram in figure 4 for this process to determine the state using the pertinent probability. • **Audio Generation:** We utilize the MIDIUti (Studach, 2018) to generate the audio mp3 file from the rhythm and tune we got from the earlier states. We undertook the duration, pitch, loudness,

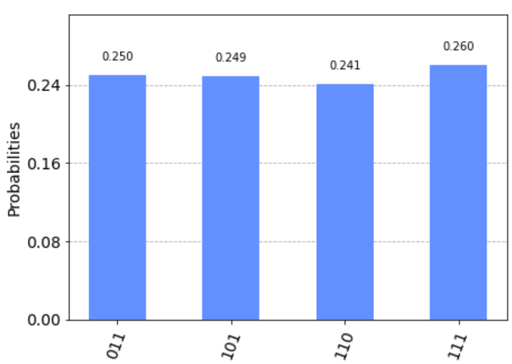

Figure 3. Histogram of note generation

and channel. The note is generated and added to each cycle. Finally, we created the mp3 audio file so that we could execute it. Our model's code is available on our GitHub repository: (Islam, Agm and Rahaman, Md Shahidur)

3.2. Web Application:

We developed an interactive web application to play the generated music to achieve our objective and motivation, and it is now open to the public. We have utilized the frontend with React.Js and ran the code we constructed for the backend to play the music in the music gallery. The publicly hosted URL link: https://qtune.thepixel.men/

4. Conclusion & Future Works

The results of our inquiry on using quantum computing in music have been encouraging. The Basak-Miranda algorithm and quantum superposition were successfully combined to create a web application that plays music created using quantum principles and functionalities. Quantum superposition generated pitches, while the Basak-Miranda method created rhythms. This implementation addresses the growing need in the music industry and provides new opportunities for programmers and lovers of quantum computing.

Future research in this area has several fascinating opportunities. Incorporating human voice into our music creation system is one potential direction. We can investigate the automation of song creation without human contact by utilizing quantum computing, which presents a revolutionary method of music composition. This human-voice integration can transform the music business by facilitating new artistic cooperation and opening new avenues for creative expression.

In conclusion, our research has established a robust framework for using quantum computing in creating music. The Basak-Miranda algorithm and quantum superposition have successfully demonstrated the transformative potential of quantum principles in developing singular and enthralling musical experiences. With more research and advancement, we see a time when quantum computing will significantly impact how music is composed and performed.

References

Boyer, M., Liss, R., and Mor, T. Geometry of entanglement in the bloch sphere. *Physical Review A*, 95(3):032308, 2017.

Bretan, M., Weinberg, G., and Heck, L. A unit selection methodology for music generation using deep neural networks. *arXiv preprint arXiv:1612.03789*, 2016.

Doornbusch, P. Computer sound synthesis in 1951: The music of csirac. *Computer Music Journal*, 28(1):10–25, 2004.

Hiller, L. and Isaacson, L. M. *Illiac suite, for string quartet*, volume 30. New Music Edition, 1957.

Islam, Agm and Rahaman, Md Shahidur. URL `https://tinyurl.com/QuantuneGit`. Project's repository .

Klco, N., Roggero, A., and Savage, M. J. Standard model physics and the digital quantum revolution: thoughts about the interface. *Reports on Progress in Physics*, 2022.

Ludwig, A. M. Culture and creativity. *American Journal of Psychotherapy*, 46(3):454–469, 1992.

Marques, M., Oliveira, V., Vieira, S., and Rosa, A. Music composition using genetic evolutionary algorithms. In *Proceedings of the 2000 Congress on Evolutionary Computation. CEC00 (Cat. No. 00TH8512)*, volume 1, pp. 714–719. IEEE, 2000.

Miranda, E. R. Quantum computer: Hello, music! *Handbook of artificial intelligence for music: Foundations, advanced approaches, and developments for creativity*, pp. 963–994, 2021.

Miranda, E. R. and Basak, S. Quantum computer music: Foundations and initial experiments. In *Quantum Computer Music: Foundations, Methods and Advanced Concepts*, pp. 43–67. Springer, 2022.

Miranda, E. R. and Bask, S. T. Quantum computer music: Foundations and initial experiments. *arXiv preprint arXiv:2110.12408*, 2021.

Olivieri, P., Askarpour, M., and Di Nitto, E. Experimental implementation of discrete time quantum walk with the ibm qiskit library. In *2021 IEEE/ACM 2nd International Workshop on Quantum Software Engineering (Q-SE)*, pp. 33–38. IEEE, 2021.

Papadopoulos, G., Wiggins, G., et al. A genetic algorithm for the generation of jazz melodies. *Proceedings of STEP*, 98, 1998.

Polkinghorne, J. *Quantum theory: A very short introduction*. OUP Oxford, 2002.

Studach, N. Robot composer framework, 2018.

Yang, X.-S., Ting, T., and Karamanoglu, M. Random walks, lévy flights, markov chains and metaheuristic optimization. In *Future information communication technology and applications*, pp. 1055–1064. Springer, 2013.