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Analysis of the Art Ecosystem in the Development of Musicmathematics

Samuel[1] *, I Wayan Mudra[2], I Ketut Sariada[3]

[1,2,3]*Institut Seni Indonesia Bali, Indonesia*
***Corresponding Author:** *samuelhadikusumaa@gmail.com*

Abstract: Musicmathematics is the integration of mathematical principles in music, offering a new approach in contemporary music composition. This study arises from the urgency to understand the impact of musicmathematics on the art ecosystem holistically, encompassing cultural, social, economic, educational, legal, and technological aspects. The research employs document analysis and audiovisual analysis methods to identify patterns, relationships, and the influence of musicmathematics on various elements of the art ecosystem. The study is based on the art ecosystem theory which emphasizes the interaction between art actors and social structures, and fractal theory which observes recurring patterns in music structures. Additionally, the concept of dynamic culture is used to understand cultural transformation through the application of mathematical innovations. The results of the research indicate that musicmathematics significantly contributes to music composition innovation, despite facing challenges in social acceptance and commercialization. Culturally, musicmathematics creates tension between innovation and tradition; socially, this genre forms a limited experimental community; and in education, it enriches curricula with analytical approaches facilitated by technology. The study concludes that musicmathematics holds great potential in supporting the transformation of contemporary arts, particularly through strengthening education and technology. However, adaptive strategies are needed to increase the acceptance of this concept in a broader art ecosystem.

Keywords: musicmathematics, art ecosystem, music innovation, music education, art technology

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Introduction

Musicmathematics is a field that integrates mathematical principles, such as fractal theory, numbers, and geometry, into music creation. The application of fractals in music, as proposed by Mandelbrot, results in repeating patterns that can be translated into musical compositions with complex structures and infinite variations. This concept opens up new opportunities in artistic exploration, where composers are increasingly adopting musicmathematics to create more innovative and meaningful contemporary musical works.

The development of musicmathematics is not limited to technical aspects or music theory, but is also influenced by dynamics within the broader art ecosystem, encompassing cultural, social, economic, educational, legal, and technological factors. According to Becker (1982), art is always related to the interaction between art actors and the surrounding social structures. In the context of music mathematics, mathematical innovation interacts with society's need for more complex art, supported by technological advancements and developments in mathematics and music education, enabling the creation of music based on scientific concepts.

This research aims to fill the gap in the existing literature regarding the impact of musicmathematics on the art ecosystem holistically. The main focus of this research is to explore how musicmathematics influences various elements within the art ecosystem, including cultural, social, economic, educational, and technological aspects, as well as the challenges faced in the acceptance of this concept within society. This research is expected to broaden understanding of the role of musicmathematics in supporting social, educational, and cultural transformation within the context of contemporary art.

Methodology

This research uses document analysis and audio-visual analysis methods to explore the phenomenon of musicmathematics within the art ecosystem in greater depth. This method aims to understand the development of the concept of musicmathematics and its impact thru various relevant sources, such as journals, books, scientific articles, and audio-visual works.

In the document analysis phase, the research mapped the development of musicmathematics theory in the context of contemporary music by examining academic literature and the works of figures such as Iannis Xenakis and Benoît B. Mandelbrot. This analysis includes a study of fractals in music and the mathematical theories used in composition, as well as their influence on compositional practice and public understanding.

At the audio-visual analysis stage, the research examines musical works that apply mathematical principles, such as fractals or number theory. This includes listening and structural understanding of musical works, as well as visual analysis of graphs or diagrams illustrating mathematical patterns in the composition.

This study explores how abstract concepts are translated into audio and visual forms that are acceptable to the audience. Additionally, the views and works of relevant figures are also examined to understand their contributions to the development of musicmathematics. This approach provides a comprehensive overview of the relationship between mathematical theory, musical practice, and societal reception of this concept, as well as its role in shaping the landscape of contemporary musical arts.

Results and discussion

Cultural Ecosystem Analysis

The cultural ecosystem encompasses a variety of interacting elements, including social values, traditions, norms, and cultural products that develop within a society. In the context of music mathematics, the cultural ecosystem focuses on how mathematical concepts in music are received, adapted, and influenced by cultural factors. Music, as part of the cultural ecosystem, not only serves as a form of artistic expression but also as a social product influenced by the norms and traditions prevalent in society.

The cultural ecosystem theory is rooted in the understanding that culture is a dynamic system that interacts with other elements in society, such as technology, economics, and education. For example, Fiske (2010) in his work *Understanding Popular Culture* argues that culture is not a static entity, but the result of negotiation between interacting social forces. Fiske emphasizes that culture is formed in the relationship between cultural products, such as music, and the broader social structures. In this case, the application of musicmathematics can be seen as a phenomenon that interacts with cultural norms and societal expectations regarding music. Furthermore, Geertz (1973b) in *The Interpretation of Cultures* explains that culture is a system of meaning constructed thru symbols and practices practiced in daily life. In this context, musicmathematics can be understood as a new symbol in the world of music, presenting a fresh understanding of how music can be created and interpreted. This process involves changes in the way society views music and art as a whole.

In a cultural context, musicmathematics can be seen as a form of innovation stemming from the interaction between art and science, which often receives mixed reactions from society. Most people, especially those tied to musical traditions, might see this concept as too technical or difficult to understand. This aligns with Susan McClary's (2002) view in *Feminine Endings*, which states that art is often in tension between tradition and innovation (Butler, 2009). Innovation in mathematics-based music might be seen as a threat to traditional musical values, which tend to emphasize emotional expression and direct connection with the audience more.

However, musicmathematics also opens up new opportunities to create more complex and structured musical forms, which may be more readily accepted in societies that are more open to experimentation and innovation. For example, the use of fractals in music creates repeating patterns that naturally captivate listeners' attention, due to their regular yet unpredictable nature. For people accustomed to more structured music, such as classical or popular music, acceptance of this form of music may take time. However, for people who are more familiar with experimental approaches and contemporary music, the concept of musicmathematics can be accepted more quickly.

This process of reception is also related to what Bourdieu (1984) in *Distinction: A Social Critique of the Judgment of Taste* calls "aesthetic ratio," which is how society judges and categorizes art forms based on taste and social tendencies. In this regard, musicmathematics might be seen as a more elite art form, accessible only to a select few with specialized knowledge of mathematics and music theory. However, over time, if more educators, musicians, and composers adopt this concept, its acceptance in popular culture could grow.

The application of musicmathematics in music not only serves as a form of artistic expression but also as a tool to test the boundaries of existing musical traditions. This challenges our understanding of music as an art form that must be emotionally accessible, replacing it with a more rational and structural understanding. In turn, this has the potential to revolutionize the paradigm of musical art within the cultural ecosystem, which could ultimately broaden the acceptance and appreciation of more innovative and theory-based types of musical works.

Social Ecosystem Analysis

The social ecosystem refers to the dynamic relationships between individuals, groups, and institutions within a society that shape values, norms, and patterns of social interaction. In the context of music mathematics, the social ecosystem refers to how the application of mathematical principles in music interacts with the broader social structure, encompassing its influence on social identity, the community of musicians, and the dynamics of society in accepting or rejecting this new form of music. Research on musicmathematics within the social ecosystem is important for understanding how innovation in mathematics-based music not only affects the creative processes of musicians, but also its impact on social relationships and public reception of such artworks.

The theoretical foundation of the social ecosystem is drawn from the social perspective of theory, which emphasizes the importance of the relationship between individuals and social structures. Durkheim (2018) in *The Division of Labor in Society* argues that social structure is formed thru collective relationships that arise from mutual agreement within society. In this regard, musicmathematics can be seen as a new element that introduces artistic forms of expression combining science and art, which indirectly changes the existing social values and norms in society. Bourdieu (2018) in *Distinction: A Social Critique of the Judgment of Taste* also notes that cultural taste, including in music, often reflects social position in society. Mathematically-based music that might be considered too technical or exclusive could be confined to certain social classes, while broader groups might reject or not appreciate such music because it's perceived as "too complex" or "too academic."

Musicmathematics holds the potential for change within the social ecosystem of music. Social acceptance of this concept is often hindered by the general public's lack of understanding of the underlying mathematical theory. As mentioned by Pierre Bourdieu, social taste in music is heavily influenced by one's cultural and educational capital (Ashwood & Bell, 2017). Individuals who lack knowledge or access to mathematical concepts in music may feel alienated from works based on musicmathematics. Even in professional settings, the acceptance of musicmathematics as a legitimate form of musical art is still limited. Many musicians and composers consider this mathematically-based music to be incompatible with more conventional traditions or esthetic tastes.

However, on the other hand, musicmathematics can also open up opportunities for the formation of new, more progressive social communities. Such as the International Society for Music Information Retrieval (ISMIR), Sound and Music, and The Algorithmic Composer Network. As technology and information have advanced, music that integrates mathematical concepts has begun to gain attention from academics and communities more open to artistic experimentation. According to Giddens (1979) in *The Constitution of Society*, social change occurs thru the interaction between social structures and individual

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agents. In this case, musicians working with musicmathematics can be agents of change influencing the social structure within the music world, opening space for shifts in esthetic values and acceptance of music.

Based on my personal experience, this phenomenon is very clear. When I first started integrating mathematical concepts into musical composition, the main challenge I faced was understanding and acceptance from the broader musical community. Many people feel that these concepts have no relevance to the emotional or esthetic experiences they typically have with music. However, on the other hand, I also felt the presence of a small group that was very open to exploring this math-based music. These groups are often more connected to technology and higher education, and they see musicmathematics as a form of art that challenges traditional boundaries.

Additionally, musicmathematics has the potential to create more inclusive social connections within the music world. In the digital age, mathematically-based music can be disseminated more widely thru online platforms that facilitate interaction between individuals from different backgrounds, both in educational and cultural aspects. Online communities and social media allow musicians working with musicmathematics to build a global audience that may not be limited to traditional audiences. This creates opportunities for international collaboration and the exchange of ideas that can break down social barriers hindering the spread of new ideas in music.

However, there are significant challenges in terms of social acceptance of musicmathematics. Many people still consider music based on mathematical theory to be merely a scientific experiment and inadequate as a form of art that can be widely enjoyed. According to McClary (1992), art exists in a tension between innovation and tradition, where new art forms are often rejected or less accepted by society because they conflict with established values or expectations. In this case, musicmathematics faces a similar tension, where the musical community prefers types of music that are easier to understand and more resonant with their emotional experiences. Therefore, one of our tasks as practitioners and researchers is to continuously open dialog about the potential of musicmathematics in breaking down these social barriers, so that mathematics-based music can be accepted and appreciated by a wider audience.

According to the author, although social challenges to the acceptance of musicmathematics are clearly present, the author believes that thru proper education and promotion, we can introduce this music to a wider audience. Acceptance of mathematically-based music requires a more inclusive approach, where public understanding of mathematical concepts can be improved. Musicmathematics can serve as a bridge between art and science that is more accessible to the general public, and enrich the social ecosystem within the world of music.

Economic Ecosystem Analysis

In the context of economics, the development of musicmathematics has implications for two main things: commercial value and impact on the music industry. Based on cultural economic theory, as explained by Throsby (2001), the economic value of art lies not only in the artwork itself, but also in the processes and experiences involved in its creation. The application of music mathematics offers added value to music by combining art with science and technology, creating a product that is potentially appealing to a specific market segment, particularly among experimental and academic music enthusiasts.

This musicmathematics ecosystem is strengthened by the technology industry, which supports the production and distribution of mathematics-based music. Software like Max/MSP, SuperCollider, and Pure Data, used for creating algorithmic music, opens up opportunities for musicians to create their work at a lower cost compared to conventional methods. However, despite the increasing number of musicians using this technology, economic challenges remain in terms of monetizing music-mathematics-based musical works. Many of these works cannot be sold in conventional formats, such as pop or commercial music, and are often found only in niche or limited markets.

According to Hesmondhalgh (2008), in his book *The Cultural Industries*, the modern music economy is increasingly driven by innovation and technology. In this case, the use of musicmathematics as an innovative method in music has the potential to influence how music is consumed, distributed, and appreciated. Nevertheless, Hesmondhalgh also emphasizes that while there is potential for monetization, there is tension between experimental art and commercialization, where highly experimental art often does not gain widespread market attention.

Analysis of the Education Ecosystem

In the context of music mathematics, the educational ecosystem plays a crucial role in facilitating the understanding and application of mathematical principles in music. Music education has long been one of the main channels for developing technical and theoretical skills for musicians. With the emergence of musicmathematics, music education must adapt to include learning about how mathematics, particularly concepts such as fractals, number theory, and algorithms, can be applied in musical composition.

Music education from elementary school to university levels already incorporates mathematical elements into its curriculum, although it primarily focuses on traditional music theory and notation. With the advancement of technology and music mathematics, some educational institutions are beginning to offer courses and study programs that focus more on the application of mathematics in musical arts, as seen in various universities that have experimental music and music technology programs. For example, institutions like Berklee College of Music and the California Institute of the Arts offer courses that integrate mathematical theory with technology-based music creation, including in algorithmic composition and fractal analysis in music.

Although there has been progress in integrating music and mathematics into education, the challenge lies in the need to systematically introduce and teach this discipline to music students. Many music education institutions still focus on traditional music theory and more general composition techniques, and only a few offer courses that delve into the application of mathematical principles. Additionally, teachers with expertise in this field are limited, and there are still

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gaps in educational resources for delving into the technical aspects of musicmathematics.

According to Hoelscher (2021) in *Mathematics and Music: Mathematical Visualization in Music Composition*, integrating mathematics into music education can open up new perspectives on how we understand and create music. He believed that, although many musicians responded to traditional music theory, future music education should include the application of mathematics to prepare musicians for the global challenges that are increasingly leading to the use of technology in music creation. Additionally, Miller (2024) in his book *Music, Mathematics and Education* emphasizes the importance of collaboration between music and mathematics instruction, with the goal of fostering critical thinking and analytical skills in musicians that can be translated into the creation of more innovative musical works.

Analysis of the Legal Ecosystem

One of the major challenges faced by musicmathematics is how this concept is treated within the legal context, particularly in terms of copyright, licensing, and intellectual property protection. Music based on algorithms or mathematical structures often raises questions about whether the work is considered an original creation or whether it is more a product of a system that can be replicated or modified by anyone.

One of the main issues in musicmathematics is whether works produced by applying algorithms or mathematical principles can be copyrighted, considering that mathematics is essentially a universal science that cannot be claimed by individuals. In this case, many composers who use mathematical algorithms in their compositions find it difficult to determine whether they are entitled to copyright over the work. So far, copyright law in many countries, including the United States and the European Union, tends to assess originality in terms of creativity in composition and execution, but does not explicitly address works generated by machines or algorithms.

On the other hand, the legal challenges in musicmathematics also involve issues of licensing and distribution of mathematical music works. Many software and programs used to create algorithmic music, such as Max/MSP and Pure Data, are available for free or under an open license. This raises questions about the business model and distribution rights for works created using the software. Copyright law here must adapt to ensure that the rights to works are still respected even tho the music creation process relies on devices or code that are publicly accessible.

According to Lawrence Lessig (2004) in his book *Free Culture: How Big Media Uses Technology and the Law to Lock Down Culture and Control Creativity*, copyright protection for works created with the help of technology and mathematics needs more attention (Lessig, 2018). Lessig argues that copyright law in the art world should be more flexible and capable of accommodating technology-based innovation, so that musicians and composers working with musicmathematics still retain their rights to their works. Meanwhile, Wendy Seltzer in *The Legal Nature of Music and Algorithms* (2013) also emphasized that

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the law needs to adapt and respond to technological changes in the arts industry so that creators can innovate safely without fear of their works being exploited without permission (Urban *et al.*, 2017).

Analysis of the Technology Ecosystem

The technology ecosystem plays a very important role in the development of musicmathematics, as technology allows musicians and composers to implement and develop mathematical concepts in musical works in a more structured and innovative way. In this case, technology serves as a bridge between mathematical theory and applicable musical practice, creating space for more complex and dynamic musical exploration.

The application of mathematics in music would not have been able to develop rapidly without technological advancements, especially in the fields of software and hardware, which enable algorithmic and mathematically structured music analysis and creation. One of the most significant examples is software like Max/MSP, Pure Data, and Supercollider, which allows musicians to process mathematical data into musical compositions. This technology allows composers to work with mathematical principles, such as number theory, geometry, or fractals, in a more practical and efficient way, rather than relying solely on theoretical or manual approaches.

In addition to software, hardware technologies such as digital synthesizers, computers, and digital recording tools have enabled the creation of sounds and compositions that are not only based on traditional instruments, but also on the exploration of sounds based on mathematical algorithms. Composers like György Ligeti, who used fractal theory in his works, and musicians like Steve Reich and Philip Glass, who utilized the concepts of minimalism and repetition in their compositions, have leveraged technology to realize their musical ideas based on mathematical principles.

Technological advancements have also significantly impacted how composers create music based on music mathematics. By using algorithm-based software, a composer can automatically create musical compositions with specific data input, which is then processed by a computer. This process allows for experimentation with more complex musical structures, such as creating sounds generated thru fractals and creating sound patterns based on chaos theory and number theory. This opens up opportunities for the creation of musical works that might have been previously unimaginable with manual techniques.

For example, works that utilize the principles of fractal geometry, such as those by composers like John Milbauer and David Cope, demonstrate how fractal concepts in musicmathematics can be translated into truly new musical compositions with structures that are not easily achieved by traditional compositional techniques. Technology also allows musicians to simulate sounds in a short amount of time, experiment with sounds and compositions without physical limitations, giving them artistic freedom to develop mathematical ideas in their musical works.

Technology not only influences the process of creating mathematics-based music but also plays a key role in disseminating musicmathematics to the wider public. With the emergence of digital platforms like YouTube, SoundCloud, and others, musicians can easily publish works that incorporate mathematical principles in music to a global audience. Additionally, technology provides opportunities to build a larger community for those interested in musicmathematics, including collaborations between musicians, mathematicians, and educators. This community thrives thru blogs, discussion forums, and online courses, enabling more open knowledge sharing about the application of mathematics in music.

In addition, open-source software like Pure Data and Supercollider also facilitates wider access for anyone who wants to learn or create with musicmathematics. This creates a more inclusive and open ecosystem where individuals from diverse backgrounds can participate in the creation of mathematical music. However, while technology has opened up many new opportunities, there are also challenges in integrating musicmathematics more widely into the world of music. One of these is dependence on complex tools and software, which require high technical skills to use effectively. Additionally, some musicians and educators may find it difficult to adopt mathematical concepts in music creation due to limitations in their understanding of mathematics or technology. Additionally, while technology offers musicians creative freedom, many argue that musicmathematics generated thru algorithm-based software can diminish the emotional element and spontaneity that often lie at the heart of traditional music creation. For example, composers and musicians working with musicmathematics often face criticism from those who believe that algorithm-based music is less capable of conveying the same emotions as manually created music.

According to Larry Polansky, a composer and music technologist, in his book *The Mathematics of Music* (2009), technology has enabled the creation of new methods in musical composition, but at the same time, he emphasizes the importance of maintaining a balance between algorithms and human expression (Sievers *et al.*, 2013). Polansky argues that although technology opens up space for innovation in musicmathematics, the presence of the human element in the music creation process remains essential. On the other hand, Iannis Xenakis, a pioneer in mathematical composition, stated in his book *Formalized Music: Thot and Mathematics in Composition* (1971) that technology not only expands the boundaries of musical expression but also opens up possibilities for creating entirely new and previously unimaginable sounds (Nierhaus, 2009).

Musicmathematics is an important phenomenon in the art ecosystem, particularly in the exploration of contemporary music that combines mathematical principles such as fractal theory and numbers to create innovative works. Becker (1982) emphasizes that art is the result of complex interactions within a social ecosystem, where musicmathematics introduces a new approach that enriches culture, although it still faces tension with mainstream musical traditions. In this context, Geertz (1973a) states that culture is a constantly evolving system of meaning, so innovations like musicmathematics have the potential to create new paradigms in art.

Socially, Bourdieu (2018) shows that the reception of art is heavily influenced by cultural capital, meaning that musicmathematics is often only accessible to experimental communities with technical backgrounds. In education, Miller (2024) emphasizes the importance of integrating mathematics into music to build analytical skills among students, although its application in the curriculum is still limited. From a technological perspective, Xenakis *et al*. (2003) assert that mathematical algorithms enable the exploration of new sounds that expand artistic boundaries, but the gap in audience reception remains a challenge. In legal aspects, Seltzer (2013) emphasizes the need for copyright law adaptation to protect algorithm-based works, which are often considered less original.

Conclusion

Overall, musicmathematics has great potential to support the transformation of contemporary art. However, adaptive strategies are needed to increase social acceptance, strengthen synergy between mathematical theory and artistic practice, and bridge the gap between technology and society. Further research is needed to address these challenges and maximize their impact within the art ecosystem.

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