http://doi.org/10.35668/2520-6524-2025-4-12
UDC 681.5.013 (045)

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NYMPHAEA LOTUS GENOME SEQUENCE TRANSFORMATION INTO MUSIC USING DNA DATABASE

Abstract. *The genetic music creation approach has been considered. Deciphering DNA sequences is based on the author's algorithm. Appropriate software targeted on reading the genome sequence and translating it to a sound series has been written.*

The use of random numbers in the musical composition makes it possible to get a musical signal that is original in structure but a little bit monotonous in its texture. With the aim of making it more interesting and eliminating the triviality of the musical score, which is a consequence of the automation of the music composition, a digital filter based on the solution of a linear differential equation in fractional derivatives operated by randomly changing the order of a fractional derivative (according to Caputo in a form of activation function of the neural scheme) is used.

Listener and creator parts of the extended version of "Aquarius" software now embrace the duality principle known in electrotechnics and applied physics.

Keywords: *genetic music, DNA music, music composing software, neural network.*

INTRODUCTION

As Wikipedia [1] states, "**Nymphaea lotus**, the white Egyptian lotus, tiger lotus, white lotus, or Egyptian white waterlily (**fig. 1**), is a flowering plant of the family Nymphaeaceae…" In ancient times the Egyptian lotus was worshipped, especially in Egypt. It was considered a symbol of creation there. In Ancient Greece, it was a symbol of innocence and modesty. The Egyptian lotus is the national flower of Egypt. It is also an element of the Coptic flag". Lotus is a symbol of Buddhism; also, "the lotus flower is revered in Japan for its ability to rise from the dirty, murky waters to bloom into a beautiful pure flower. This process symbolizes attaining enlightenment. The idea is that we can rise above human suffering in the same way as the lotus by moving from the lowest to the highest state of consciousness" [2].

Fig. 1. Nymphaea lotus

To listen to this hidden music of Nature, it is needed to translate the original 4-note harmony to any desirable classical musical harmonies (scales). In this research, a diatonic harmony in C major scale is being used, though it could have been any other one, including a chromatic, pentatonic, natural or harmonic minor, etc.

In **fig. 2**, general info of the complete genome of Nymphaea lotus chloroplast is represented [3; 4]:

A specific fragment chosen manually will be investigated and translated into music in this research. By applying the highest possible zoom, the series of nucleotides can be seen for any desired code segment (**Fig. 3**):

So, thymine (t), adenine (a), guanine (g), and cytosine (c) are the four chemical bases that make up the genetic code of our DNA fragment.

ACTUALITY OF THE TOPIC

New methods of musical composition are always a very desirable subject of studies in the world's scientific, educational, psychological, and musical societies. Also, it's of great importance to create novel ways of generating music's perception and understanding. For these reasons, and not only these, the theme of the scientific investigation is also approximately up to date. Also, novel peculiar machine learning algorithms are very welcome by today's science related to the niche, since the

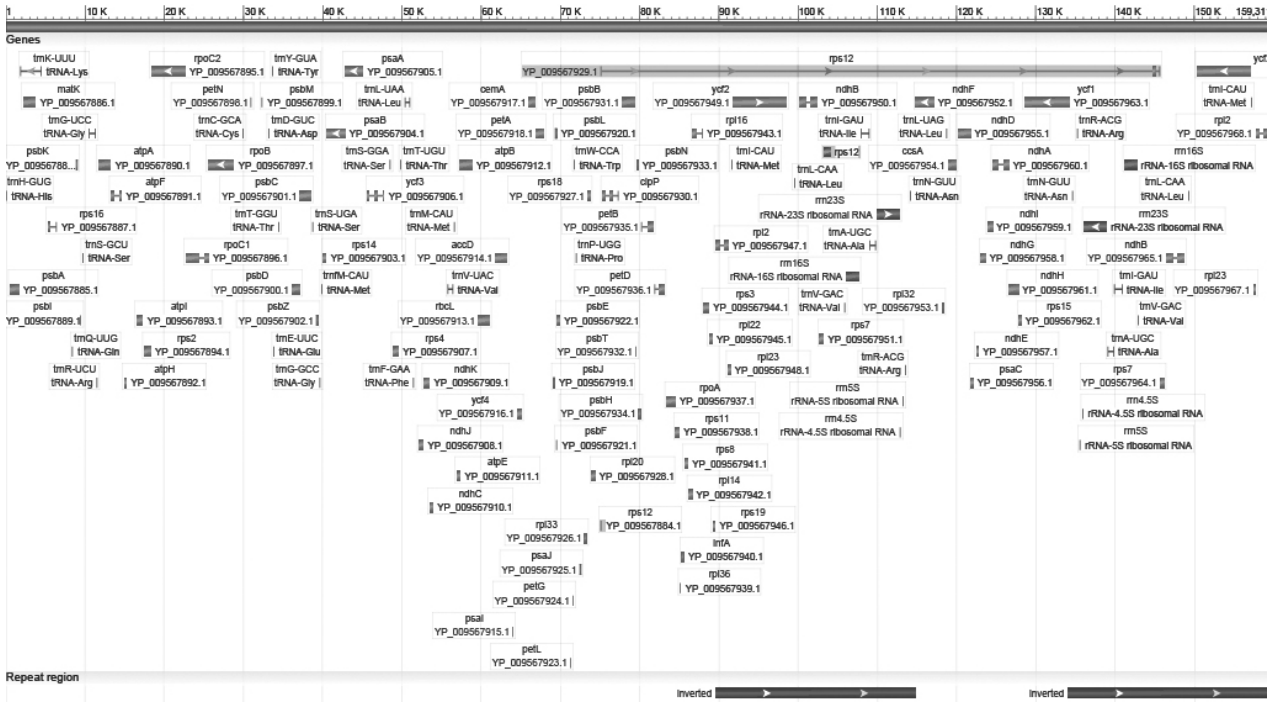

Fig. 2. NCBI database Reference Sequence: NC_041238.1

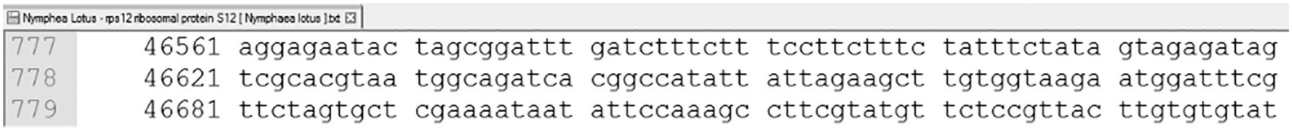

Fig. 3. A particular segment of NCBI database Reference Sequence: NC_041238.1

branch being uncovered seems to have been experiencing its second or even third birth.

RESEARCH PURPOSE

The development of an implementation of a biotechnical software automated control system intended for creating sound sequences from DNA nucleotide sequences — has been achieved.

RESEARCH PUBLICATIONS

The theoretical method of protein music, DNA music, or genetic music (different names are in active use) was developed by American physicist, composer, and mathematician Douglas Richard Hofstadter [5] in 1979 in his book “Gödel, Escher, Bach: An Eternal Golden Braid” [6]. The connection between music (composing) and mathematics is well shown in [7; 8]. In [9] has been investigated fractional calculus application for different applied problems. Techniques for automatic music composition using machine learning (genetic algorithms), and some practical applications of this technology are listed in [10–17; 19].

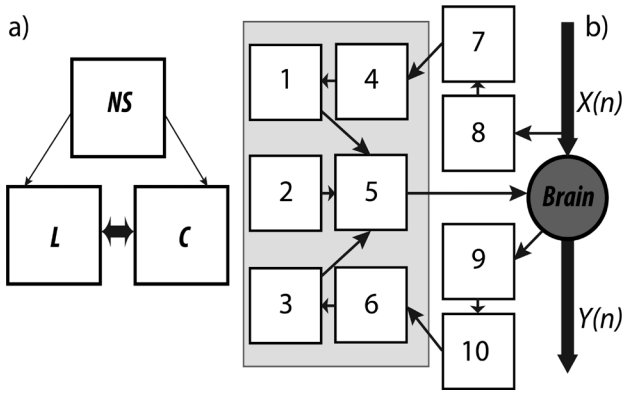

Fig. 4. a) The structural scheme of NN; NS — main neural scheme; L — listener; C — creator; b) Detailed NS of the electronic composer

Structural scheme. In **fig. 4 a**, a structure of the neural network scheme (NS) has been presented, upon which the main and some additional algorithms of classical electronic music creation software can be used.

Mathematical algorithm. It has been previously described in [18] and is available online for free.

Practical realization. The NS in greater detail has been shown below (**fig. 4 b**):

Here:

1) The block of operating actions BOA (the subblock of translation operators, the subblock of transfer function).

2) The sensor of a medium condition (SMC). The given block is the recipient and the analyzer of an entering signal, which generally can be both digital and analog.

3) The sensor of an object condition (SOC studies the influence of ACS on object control — the brain of the patient).

4) A digital-to-analog converter (DAC) is necessary for transforming analog initial signals (if any) into digital ones. In the case of a digital initial signal, this block is subject to elimination.

5) The module of estimation of the object condition (MEOC) treats the digital signal received from SOC and supplements a database of the object condition.

6) The module of estimation of the medium condition (MEMC) treats the digital signal received from SOM and supplements a database of a medium condition.

7, 8) The database of medium condition (DMC) and a database of the object condition (DOC) are necessary for regulation of the BOA signal.

9, 10) The database of control algorithms (DCA) (stores a population of feedback signal translation operators, which can be used for synthesis of advanced audio series) and a database of the corresponding automation operators (3).

The control object (COT) in our case is the brain of a person using the software developed.

Practical realization, pt. 1. A general equation connecting input (P), a weight matrix that can be treated as a translation operator (W), and output (A) is shown below. It works for any NS structure possible (it's given without taking into account bias B).

$$\begin{vmatrix} w_{1,1} & w_{1,2} & \dots & w_{1,N} \\ w_{2,1} & w_{2,2} & \dots & w_{2,N} \\ \dots & \dots & \dots & \dots \\ w_{N,1} & w_{N,2} & \dots & w_{N,N} \end{vmatrix} \bullet \begin{vmatrix} p_1 \\ p_2 \\ \dots \\ p_N \end{vmatrix} = \begin{vmatrix} a_1 \\ a_2 \\ \dots \\ a_N \end{vmatrix}$$

Or, more specifically, depending on time *t*:

$$\overset{*}{s}(t) = \begin{vmatrix} s_{1,1}(t) & s_{1,2}(t) & \dots & s_{1,N}(t) \\ s_{2,1}(t) & s_{2,2}(t) & \dots & s_{2,N}(t) \\ \dots & \dots & \dots & \dots \\ s_{N,1}(t) & s_{N,2}(t) & \dots & s_{N,N}(t) \end{vmatrix} \bullet \begin{vmatrix} \xi(t)_1 \\ \xi(t)_2 \\ \dots \\ \xi(t)_N \end{vmatrix} = \begin{vmatrix} \overset{*}{s}(t)_1 \\ \overset{*}{s}(t)_2 \\ \dots \\ \overset{*}{s}(t)_N \end{vmatrix}$$

Practical realization, pt. 2. The use of random numbers in the music composition (this was mainly done for comparison and testing purposes in a Creator block from **fig. 4 a**) — allows a composer to obtain the original by its inner structure, but it is somewhat monotonous in sounding a musical signal. To breathe into it a bit more sophistication, and for the reason of elimination of factor of triviality that could be perceived as inevitable automation consequence of the music process, it was decided by the author to use as a transfer function a digital filter built on a solution to a linear differential equation in fractional derivatives (by Caputo) (1) with initial conditions (2):

$$ {}_0^C D_x^{\beta(\Omega)} y(x) + a(x) y(x) = f(x) \qquad (1)$$

$$ y(0) = y_0, \quad 0 \le x < X, \quad 0 < \beta(\Omega) < 1, \qquad (2)$$

where:

$$ {}_0^C D_x^{\beta(\Omega)} y(x) = \frac{1}{\Gamma(n-\beta)} \int_0^x (x-\tau)^{n-\beta(\Omega)-1} \frac{\partial y^n(\tau)}{\partial \tau^n},$$

$$ n-1 < \beta < n$$

and

$$ \Gamma(n-\beta) = \int_0^\infty e^{-t} t^{n-\beta-1} dt, \quad \mathrm{Re}(n-\beta) > 0,$$

$y(x)$ — the desired output of a musical signal.

Ω in (1) is a random value with a certain distribution, each time chosen uniquely for each musical piece written. So, in equations (1–2), the order of fractional derivative is operated by realization of a random process.

Also, here one can use an automation operator to convert the input signal, presented in a complex form, into a target sound series by multiplying the first one by a random process' realization-dependent functions' $f(\alpha), f(t), f(\Omega)$ impacted phase factor ψ.

Genome-based music synthesis. The decoded by a Listener block from **fig. 4 a** (with the help of an extended version of "Aquarius" software) sequence fragment of the Nymphaea Lotus Chloroplast SB12 genome is presented in **fig. 5**:

CONCLUSION

Genetic music can be composed by using the software technology proposed, which seems to be today a somewhat new approach in the scientific-psychological-musical world. Also, created before and developed in this research, automatic music creation techniques can help to maintain a balance between listening (to music) and its creation, which is important, because a human being has been given both ears and a voice.

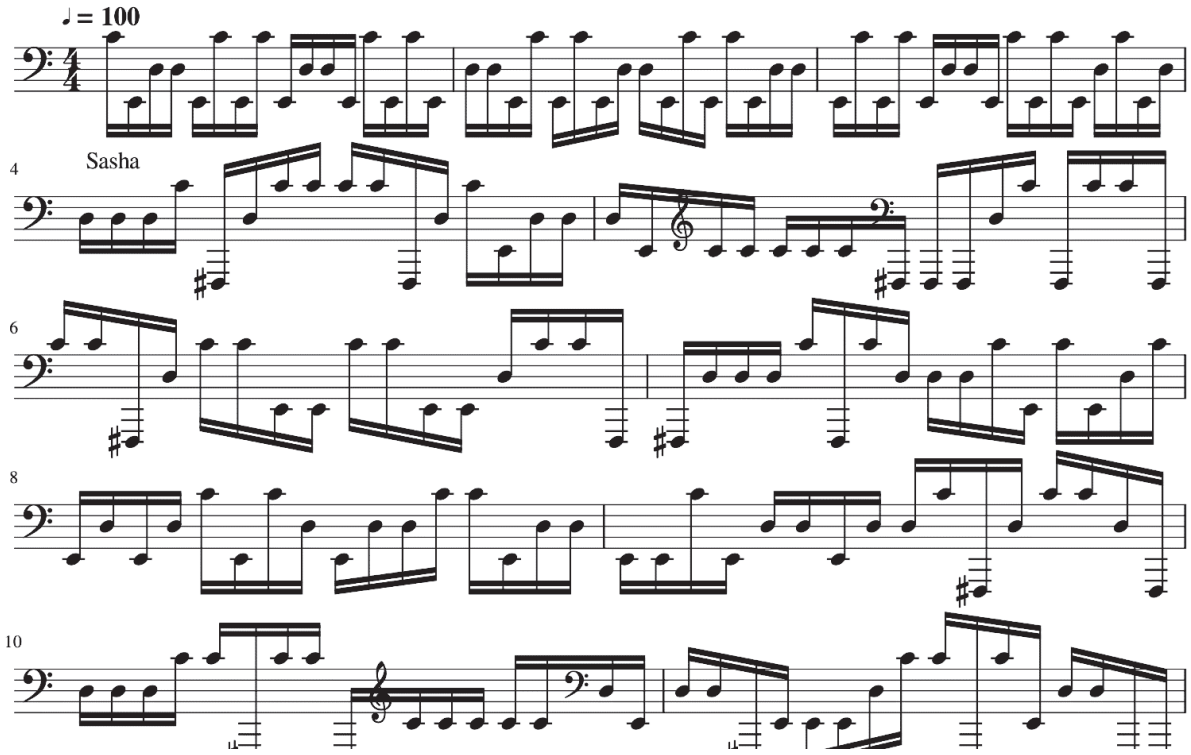

Fig. 5. The score of Nymphaea Lotus (diatonic harmony, C major scale)

The sound of the genetic music decoded from the DNA sequence of Nymphaea lotus is a surprisingly specific one. It could be applied not only for the direct objective of the research but also for strategic genome sequence research for many different biological organisms. Further investigations should be performed to understand its nature better (up to a point), but at a first glance a hypothesis can be made that the origin of this decrypted series is not quite random but instead perhaps premeditatively created by Nature with a certain aim.

"Aquarius" software, created by the author of this publication before, now has a "subdivision" — a specialized subroutine A.1, designed for DNA music deciphering, presentation in the form of a classical musical score, and afterwards playing it with a musical instrument or instruments, or singing (upon the desire of a happy possessor).

REFERENCES

1. *Nymphaea lotus*. Wikipedia. Retrieved from: https://en.wikipedia.org/wiki/Nymphaea_lotus.
2. (2011). *Lotus — showing the way to enlightenment*. The japantimes. Retrieved from: https://www.japantimes.co.jp/community/2011/02/05/our-lives/lotus-showing-the-way-to-enlightenment/#.XmYogHIzbIU.
3. *Nymphaea lotus chloroplast, complete genome.* NIH. National Library of Medicine. Retrieved from: https://www.ncbi.nlm.nih.gov/nuccore/NC_041238.1?report=gbwithparts&log$=seqview&to=159311.
4. *Nymphaea lotus chloroplast, complete genome.* NCBI Reference Sequence: NC_041238.1. [NIH. National Library of Medicine. Retrieved from: https://www.ncbi.nlm.nih.gov/nuccore/NC_041238.1?report=graph.
5. *Douglas Hofstadter.* Wikipedia. Retrieved from: https://en.wikipedia.org/wiki/Douglas_Hofstadter.
6. *Gödel, Escher, Bach*. Wikipedia. Retrieved from: https://en.wikipedia.org/wiki/G%C3%B6del,_Escher,_Bach.
7. Benson, D. J. (2007). *Music: a mathematical offering.* Cambridge : Cambridge University Press, 426 p.
8. Roberts, G. E. (2016). *From music to mathematics: Exploring the connections.* Baltimore : MD: Johns Hopkins University Press, 320 p.
9. Vasilev, V. V., & Suymak, L. A. (2008). Drobnoe ischislenie i approksimatsionnye metody v modelirovanii dinamicheskikh sistem [Fractional calculus and approximation methods in modeling dynamic systems]. 256 p. DOI: 10.5281/zenodo.8426. [in Ukr.]
10. Yuksel, A. C., Karci, M. M., Uyar, A. S. (2011). *Automatic music generation using evolutionary algorithms and neural networks.* Proceedings of Innovations in Intelligent Systems and Applications (INISTA), P. 354–358.
11. Özcan, E., & Erçal, T.; in Monmarché, N., Talbi, E. G., Collet, P., Schoenauer, M., Lutton E. (Eds.) (2008). A genetic algorithm for generating improvised music. Artificial Evolution, EA 2007. *LNCS*, *4926*, 266-277.
12. Tuohy, D. R., & Potter, W. D. (2005). A genetic algorithm for the automatic generation of playable guitar tablature. *Proceedings of the International Computer Music Conference*. Barcelona, 499-502.

13. Colombo F., Seeholzer, A., & Gerstner, W.; in: Correia, J., Ciesielski, V., Liapis, A. (eds.) (2017). Deep artificial composer: a creative neural network model for automated melody generation. Computational Intelligence in Music, Sound, Art and Design, EvoMUSART 2017. *LNCS, 10198,* 81-96.
14. Takano, M., Osana, Y. (2012). Automatic composition system using genetic algorithm and N-gram model considering melody blocks. *Proceedings of IEEE Congress on Evolutionary Computation*. Brisbane. DOI: 10.1109/CEC.2012.6256522.
15. Zheng, X., Li, D., Wang, L., Zhu, Y., Shen, L., & Gao, Y. (2017). Chinese folk music composition based on genetic algorithm. *Proceedings of 3rd International Conference on Computational Intelligence and Communication Technology (CICT).* Ghaziabad. 1-6.
16. Matic, D. (2010). A genetic algorithm for composing music. *Yugoslav journal of operations research, 20* (1), 157-177. DOI: 10.2298/YJOR1001157M.
17. Vickers, P., Hogg, B., & Worrall, D. (2017). Aesthetics of sonification: Taking the subject-position. *The Body, Sound and Space in Music and Beyond: Multimod al Explorations*. Oxford, P. 89-109. DOI: 10.4324/9781315569628-6.
18. Vishnevsky, A. V. (2019). Automated music composing with normal random numbers distribution as “informational DNA” sequencing. *Naukoiemni tekhnolohii* [Science-intensive technologies], *42* (2), 177-184. DOI: https://doi.org/10.18372/2310-5461.42.13749.
19. Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience, 15* (3), 170-180. DOI: 10.1038/Nrn3666.

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ

1. Nymphaea lotus [Electronic resource] // Wikipedia. — Access mode: https://en.wikipedia.org/wiki/Nymphaea_lotus.
2. Lotus — showing the way to enlightenment [Electronic resource] // The japantimes. — 2011. — Access mode: https://www.japantimes.co.jp/community/2011/02/05/our-lives/lotus-showing-the-way-to-enlightenment/#.XmYogHIzbIU.
3. Nymphaea lotus chloroplast, complete genome [Electronic resource] // NIH. National Library of Medicine. — Access mode: https://www.ncbi.nlm.nih.gov/nuccore/NC_041238.1?report=gbwithparts&log$=seqview&to=159311.
4. Nymphaea lotus chloroplast, complete genome. NCBI Reference Sequence: NC_041238.1 [Electronic resource] // NIH. National Library of Medicine. — Access mode: https://www.ncbi.nlm.nih.gov/nuccore/NC_041238.1?report=graph.
5. Douglas Hofstadter [Electronic resource] // Wikipedia. — Access mode: https://en.wikipedia.org/wiki/Douglas_Hofstadter.
6. Gödel, Escher, Bach [Electronic resource] // Wikipedia. — Access mode: https://en.wikipedia.org/wiki/G%C3%B6del,_Escher,_Bach.
7. *Benson D. J.* Music: a mathematical offering / D. J. Benson. — Cambridge : Cambridge University Press, 2007. — 426 p.
8. *Roberts G. E.* From music to mathematics: Exploring the connections / G. E. Roberts. — Baltimore : MD: Johns Hopkins University Press, 2016. – 320 p.
9. *Васильев В. В.* Дробное исчисление и аппроксимационные методы в моделировании динамических систем: научное издание / В. В. Васильев, Л. А. Симак. — Киев : НАН Украины, 2008. — 256 с. DOI: 10.5281/zenodo.8426.
10. *Yuksel A. C.* Automatic music generation using evolutionary algorithms and neural networks / A. C. Yuksel, M. M. Karci, A. S. Uyar // Proceedings of Innovations in Intelligent Systems and Applications (INISTA). — 2011. — P. 354–358.
11. *Özcan E.* A genetic algorithm for generating improvised music / E. Özcan, T. Erçal; N. Monmarché, E. G. Talbi, P. Collet, M. Schoenauer, E. Lutton (Eds.) Artificial Evolution, EA 2007 // LNCS. — 2008. — Vol. 4926. — P. 266–277.
12. *Tuohy D. R.* A genetic algorithm for the automatic generation of playable guitar tablature / D. R. Tuohy, W. D. Potter / Proceedings of the International Computer Music Conference. — Barcelona, 2005. — P. 499–502.
13. *Colombo F.* Deep artificial composer: a creative neural network model for automated melody generation / F. Colombo, A. Seeholzer, W. Gerstner; J. Correia, V. Ciesielski, A. Liapis (Eds.) // Computational Intelligence in Music, Sound, Art and Design, EvoMUSART 2017. LNCS. — 2017. — Vol. 10198. — P. 81–96.
14. *Takano M.* Automatic composition system using genetic algorithm and N-gram model considering melody blocks / M. Takano, Y. Osana // Proceedings of IEEE Congress on Evolutionary Computation. — Brisbane, 2012. DOI: 10.1109/CEC.2012.6256522.
15. Chinese folk music composition based on genetic algorithm / X. Zheng, D. Li, L. Wang, Y. Zhu, L. Shen, Y. Gao // Proceedings of 3rd International Conference on Computational Intelligence and Communication Technology (CICT). — Ghaziabad, 2017. — P. 1–6.
16. *Matic D.* A genetic algorithm for composing music / D. Matic // Yugoslav journal of operations research. — 2010. — No. 20 (1). — P. 157–177. DOI: 10.2298/YJOR1001157M.
17. *Vickers P.* Aesthetics of sonification: Taking the subject-position / P. Vickers, B. Hogg, David Worrall; in the Body, Sound and Space in Music and Beyond: Multimod al Explorations; C. Wöllner ed. — Oxford : Routledge, 2017. — P. 89–109. DOI: 10.4324/9781315569628-6.
18. *Vishnevsky A. V.* Automated music composing with normal random numbers distribution as “informational DNA” sequencing / A. V. Vishnevsky // Наукоємні технології. — 2019. — Т. 42. — No. 2. — С. 177–184. DOI: https://doi.org/10.18372/2310-5461.42.13749.
19. *Koelsch S.* Brain correlates of music-evoked emotions / S. Koelsch // Nature Reviews Neuroscience. – 2014. — No. 15 (3). — P. 170–180. DOI: 10.1038/nrn3666.

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ТРАНСФОРМАЦІЯ ГЕНОМУ *NYMPHAEA LOTUS* В МУЗИКУ З ВИКОРИСТАННЯМ БАЗИ ДАНИХ ДНК

Резюме. *У статті розглянуто підхід до створення генетичної музики. Розшифровка послідовності ДНК ґрунтується на оригінальному авторському алгоритмі. Розроблено відповідне програмне забезпечення, що спрямоване на зчитування нуклеотидної послідовності геному та його трансформацію в діатонічний звуковий ряд.*

Використання випадкових чисел у музичній композиції дає змогу отримати музичний сигнал, що є оригінальним за структурою, проте дещо монотонним за своєю текстурою. Задля того, щоб зробити його цікавішим та уникнути тривіальності музичної партитури, що може бути результатом автоматизації музичної композиції, використовується цифровий фільтр (у формі функції активації застосовуваної нейронної схеми) на основі розв'язання лінійного диференціального рівняння з дробовими похідними (за Капуто), порядок диференціювання якого регулюється випадковим чином.

Розроблені блоки розширеної версії програмного забезпечення Aquarius — «Слухач» і «Креатор» — тепер охоплюють принцип дуалізму, відомий в електротехніці та прикладній фізиці.

Ключові слова: *генетична музика, ДНК-музика, програмне забезпечення для музичної композиції, нейронна мережа.*

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Надійшла до редакції 07.11.2025

http://doi.org/10.35668/2520-6524-2025-4-13
УДК 004.8:174.7

М. В. ПОТОЦЬКИЙ

ШТУЧНИЙ ІНТЕЛЕКТ В ІТ: ІННОВАЦІЇ, ЕТИКА ТА ВПЛИВ НА БІЗНЕС

Резюме. *У статті розкрито інноваційний потенціал технологій штучного інтелекту в інформаційних технологіях, при цьому увагу зосереджено на їхньому впливі на бізнес-середовище, суспільство та етичні аспекти впровадження. Здійснено комплексний аналіз сучасних підходів до використання штучного інтелекту в глобальному та національному контекстах. На основі SWOT-аналізу визначено сильні сторони України, зокрема високий рівень технічної підготовки фахівців і динамічний розвиток IT-сектору, а також ключові загрози та виклики: нормативно-правову неврегульованість, низьку цифрову грамотність та інституційну нестабільність. Окрему увагу приділено етичним аспектам застосування штучного інтелекту, включаючи ризики для приватності, прозорості алгоритмів і дискримінаційних наслідків. Аналіз міжнародного досвіду показав необхідність адаптації глобальних етичних стандартів до українських реалій з урахуванням культурного та правового контексту. Запропоновано практичні рекомендації щодо формування національної стратегії*