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Applying the African Buffalo Optimization Algorithm to Enhance Pedagogical Approaches

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Abstract

Algorithms are to Artificial Intelligence what mathematical formulas are to Mathematics. Algorithms form the bedrock upon which Artificial Intelligence thrives. The African Buffalo Optimization algorithm which is inspired by the behavior of African buffalo herds that use a collective intelligence approach to optimize their movement and grazing patterns can be applied to pedagogy to improve learning outcomes. In this paper, the African Buffalo Optimization algorithm which is a nature-inspired Artificial Intelligence technique is applied to pedagogy. Using the analytical research method since it is not a experimental paper, it was observed that the algorithm has wide applications to pedagogy, especially, in the areas of optimizing learning paths, resource allocation, assessment and evaluation as well as curriculum design. Other areas of usefulness, though outside the scope of this paper, include automated grading, student grouping, data analysis and learning environment design schemes. Given the above, the study, safely, concludes that the African Buffalo Optimization algorithm is a veritable tool to optimize pedagogical approaches, leading to improved learning outcomes and more efficient use of resources. It is, therefore, recommended that other optimization techniques such as Particle Swarm Optimization, Cuckoo Search and the Genetic Algorithm should be investigated to unravel their impact on pedagogy.

Keywords: African buffalo optimization, digitization, learning, pedagogy

Applying the African Buffalo Optimization Algorithm to Enhance Pedagogical Approaches

African Buffalo Optimization (ABO) is a nature-inspired optimization algorithm designed by Odili and Kahar in 2015 (Odili Kahar, Noraziah, & Kamarulzaman, 2017). The relatively new algorithm draws its inspiration from the migrant attitudes of the African buffalos over the large African grasslands, savannahs and forests in search of fresh green grasses to satisfy their humongous appetites (Odili, Kahar, & Anwar, 2015). These large African wild herbivores are able to control their extremely large herds using just two basic vocalizations: /waaa/ and /maaa/. The /waaa/ call urges the buffalos to move away from their current positions into a new one, probably, due to the present location proving to be unsafe or because it has been thoroughly grazed. So the /waaa/ vocalizations is used to urge the animals to move out of a starving location to a more rewarding one (Odili, Nasser, Noraziah, Wahab, & Ahmed, 2022).

On the other hand, the /maaa/ calls are used to encourage the animals to remain in their present location because it still has enough resources. The most amazing thing about these calls is the way they are used in a 'democratic manner'. In fact, it has been observed that the buffalos engage in elections before they take decisions affecting the generality of the herds (Sapien, 2024). In terms of the movements, once the /waaa/ calls become dominant, the animals tend to gather in a given location. After the gathering, it was observed that each animal makes his calls, looks toward a direction and stoops. This tends to be done in turns, The /maaa/ callers, simply, stoop after their calls but the /waaa/ callers will always look at a direction. In many of such instances, researchers noticed that the movement or otherwise of the animals is usually towards the decision of the majority. In days where the buffalos differ sharply, it was discovered that they graze in smaller groups in diverse locations. (McLendon, 2012) The ABO was designed to simulate the decision-making process of the African buffalos. The ABO algorithm is presented below (Odili, Noraziah, & Babalola, 2020):

1. Initialize the buffalos within the search space;
2. Calculate the buffalos' exploitation:

$$m_k' = m_k + lp1(bg - w_k) + lp2(bp_k - w_k)$$

3. Calculate the buffalo's locations using:

$$w_k' = \frac{?w_k + m_k?}{\lambda}$$

4. Determine if the ????s updating Yes, proceed to 5. Else return to 2
5. Crosscheck stopping criteria. Not reached, return to step 2, else proceed to 6
6. Output best solution.

On its part, pedago010gy refers to the Art, Science, and practice of teaching, particularly in a formal educational setting (Petrenko, 2024). It encompasses various aspects, including:

i. Teaching methods: Strategies and approaches used to convey knowledge and skills.
ii. Learning theories: Understanding how students absorb and process information.
iii. Curriculum design: Creating and organizing content to achieve learning objectives.
iv. Assessment and evaluation: Measuring student progress and understanding.
v. Instructional materials: Resources and tools used to support teaching and learning.
vi. Classroom management: Creating a productive and respectful learning environment.
vii. Teacher-student relationships: Building trust, empathy, and rapport to foster learning.
viii. Diversity and inclusion: Addressing diverse learning needs, cultures, and abilities.
ix. Technology integration: Leveraging technology to enhance teaching and learning.
x. Continuous professional development: Teachers' on-going learning and growth (Gravett, Taylor, & Fairchild, 2024).

From the designed perspective of the ABO, described above, the algorithm is able to optimize curriculum design, ensuring that learning objectives, assessments, and instructional strategies are aligned and effective, help teachers create optimized lesson plans, incorporating the most effective teaching strategies, resources, and assessments and optimize adaptive assessments, adjusting

difficulty levels, content, and format to individual students' needs and abilities. As such, the African buffalo herds adapt to changing environments and predator threats by adjusting their movement patterns and group formations. The pedagogical application of this is that ABO-inspired adaptive learning systems can adjust the difficulty level, content, and format of learning materials based on individual students' performance, learning style, and pace. (Odili & Mabude, 2024).

In all, effective pedagogy is crucial for students' success, as it helps create an engaging, supportive and inclusive learning environment that cater to diverse learners' needs. The continuous search for improvement in pedagogy is the motivation for this study. In this digital age, there is no over engagement of technology in the pedagogical process (Santoveña-Casal & López, 2024).

The literature review of Artificial Intelligence (AI) techniques deployment to pedagogy highlights the potential of AI to enhance teaching and learning (Gašević, Siemens, & Sa diq, 2023). Key findings include the application of AI technique to personalized learning. AI techniques have been found to tailor learning experiences to individual students' needs and abilities. Similarly the application of AI methodologies and tools have been successfully applied to intelligent tutoring systems: AI-powered systems provides one-on-one support and feedback to students' leading to a more effective teaching-learning process (Abulibdeh, Zaidan, & Abulibdeh, 2024) .

Moreover, some of the most successful utilization of AI resources to pedagogy is in the area pf automated grading. AI helps automate the grading process, freeing up instructors' time. Natural language processing sub-domain of AI has been quite dominant in pedagogical interventions. AI-powered tools have been found to immensely improve language learning and literacy skills (Qian et al., 2022).

Furthermore, adaptive assessments of learners have benefitted from AI interventions in teaching-learning processes. AI techniques help to create adaptive assessments that adjust the students' level of difficulty and content in real-time. Also, from the literature, AI has been

successfully assisted in learning analytics: AI techniques help in the analysis of large amounts of data to provide insights into students' learning and behaviour (Rudniy, 2024).

Again, some studies have applied AI techniques to virtual learning environments: AI techniques are used to create immersive and interactive virtual learning environments (Kayyali, 2024). In addition, teachers' support is a crucial aspect of AI intervention in pedagogy all over the literature. AI techniques, methodologies and tools help support teachers with tasks such as lesson planning, methodologies and curriculum development (Dogan, Goru Dogan, & Bozkurt, 2023). In summary, the main areas of intersection between the AI and Education are:

Intelligent Tutoring Systems

a. Natural Language Processing (NLP): Enables intelligent tutoring systems to understand and respond to students' natural language inputs, providing personalized feedback and guidance.

b. Knowledge Representation: Allows intelligent tutoring systems to represent and reason about complex knowledge domains, providing students with accurate and relevant information.

Learning Analytics and Visualization

a. Data Mining: Analyzes large datasets to identify patterns and trends in student learning behavior, providing insights for teachers and administrators.

b. Visualization Tools: Uses data visualization techniques to present complex learning data in an intuitive and actionable format, facilitating data-driven decision-making.

Accessibility and Inclusion

a. Speech Recognition: Enables students with disabilities to interact with learning systems using voice commands, promoting accessibility and inclusion.

b. Multimodal Interaction: Allows students to interact with learning systems using multiple modalities, such as text, speech, and gestures, catering to diverse learning needs

Teacher Support and Professional Development

a. Teacher Assistants: Uses AI to provide teachers with personalized support and feedback,

helping them to improve their instructional practices.

b. Professional Development Platforms: Offers AI-powered professional development platforms that provide teachers with tailored learning pathways, resources, and assessments (Dogan, Goru Dogan, & Bozkurt, 2023).

In view of the above, the research gap/pedagogical challenge that ABO aims to address is the need for adaptive, personalized, and effective learning strategies that can optimize student learning outcomes in diverse educational contexts. This is due to the observed limitations of some existing optimization techniques in their applications to diverse optimization problems. To the best of our knowledge, there is no swarm optimization technique applied specifically to pedagogy. For instance, the Genetic Algorithm (GA) has the weakness of getting stuck in local optima, and its computational complexity can be high. Similarly, the Particle Swarm Optimization (PSO) suffer from premature convergence, and its performance can be sensitive to parameter settings. Similarly, the Simulated Annealing (SA) can be computationally expensive, and its convergence rate can be slow.

The choice of the ABO arose out of our belief that it is uniquely suited to address the research gap/pedagogical challenge because ABO draws inspiration from the adaptive, cooperative, and resilient behavior of African buffalo herds, making it well-suited for optimizing complex educational systems. Moreover, ABO can adapt to changing educational contexts, student needs, and learning goals, making it an effective approach for optimizing student learning outcomes. In conclusion, while AI techniques show promise in pedagogy, concerns around bias, ethics, and teacher job displacement must be addressed (Sevnarayan & Potter, 2024). Overall, though AI has the potential to enhance pedagogy, careful consideration and research are needed to ensure effective and responsible implementation, hence, the need to apply optimization techniques such as the African Buffalo Optimization algorithm.

Method

Being an analytical research paper, in applying the African Buffalo Optimization Algorithm to pedagogy, the following steps are recommended:

Step 1: Problem Identification

i. Define learning objectives: Identify specific pedagogical challenges or objectives (e.g., optimizing learning paths, optimizing learning resources, curriculum development etc.).

ii. Collect data: Gather relevant data on optimizing learning paths, optimizing learning resources, curriculum development etc.

iii. Formulate optimization problem: Frame the pedagogical challenge as an optimization problem (e.g., maximizing students learning, learning resources and student engagement).

Step 2: ABO Algorithm Implementation

i. Define fitness function

ii. Initialize buffalo population: Represent potential pedagogical strategies as "buffaloes" with attributes (e.g., teaching methods, assessment techniques).

iii. Define fitness function: Evaluate pedagogical strategies based on learning objectives (e.g., students' engagement, academic achievement).

iv. Selection operator: Select top-performing buffaloes based on fitness function.

v. Choose the best buffalo based on fitness.

vi. Repeat the process until convergence

vii. Monitor convergence: Track optimization progress, adjusting parameters as needed.

viii. Output the best buffalo as the recommended strategy

Step 4: Implementation and Evaluation

i. Implement optimized strategies: Apply refined pedagogical approaches in educational settings.

ii. Evaluate effectiveness: Assess students' outcomes, gathering data on engagement, achievement, and retention.

iii. Refine and adapt: Continuously refine strategies based on evaluation results.

African Buffalo Optimization to Pedagogy

Optimization has become so widespread in modern science and engineering research enterprises (Odili & Mohmad Kahar, 2016). This pride of place of optimization in modern-day research efforts

is a motivation for this study. Some ways ABO can be applied to pedagogy include optimizing learning paths, resource allocation, curriculum design as well as in assessment and evaluation (Odili, 2018) . Let us examine these in some detail.

African Buffalo Optimization to Optimizing Learning Paths

ABO when programmed in a programming language such as MATLAB, Java, C++ and C# etc. can be applied to optimize learning paths by:

i. Identifying optimal learning sequences: ABO can determine the most effective sequence of learning topics to maximize knowledge retention and skill acquisition.

ii. Adapting to individual learners: ABO can adapt learning paths to individual learner's needs, abilities, and learning styles.

iii. Optimizing resource allocation: ABO can optimize resource allocation, assigning the most effective resources (e.g., teachers, materials) to each learner.

iv. Dynamic adjustment: ABO can dynamically adjust learning paths based on learners' progress, reinforcing strengths and addressing weaknesses.

v. Minimizing learning time: ABO can minimize the time required to achieve learning objectives, maximizing efficiency.

vi. Maximizing learning outcomes: ABO can maximize learning outcomes, ensuring learners achieve their full potential.

To achieve the above, the parameters to be considered are the available learning resources, number of students, learning time allocated, learning paths (full-time, part-time, sandwich mode etc.) and the expected learning outcomes. From the foregoing, it is clear that by applying ABO to optimize learning paths, educators can create personalized, efficient, and effective learning experiences for their students.

African Buffalo Optimization to Resource Allocation

ABO when programmed in a programming language like MATLAB, Java, Python, C++ etc. can be applied to resource allocation in education by:

i. Optimizing teachers' assignment: ABO can assign teachers to classes to maximize their strengths and minimize weaknesses.

ii. Resource distribution: ABO can allocate resources (e.g., textbooks, technology) to maximize learning outcomes.

iii. Scheduling optimization: ABO can optimize schedules to minimize conflicts and maximize learning time.

iv. Budget allocation: ABO can allocate budget resources to maximize impact on learning outcomes.

v. Facility allocation: ABO can assign students to facilities (e.g., classrooms, labs) to maximize learning outcomes.

vi. Support staff allocation: ABO can assign support staff (e.g., counselors, librarians) to maximize student support.

To achieve the above, ABO considers such parameters as the teachers' strengths and weaknesses, students' needs and abilities, resource availability and constraints, learning objectives and outcomes as well as budget and facility constraints (Odili, Noraziah, Alkazemi, & Zarina, 2022). As such, by deliberate application of ABO to resource allocation, educators can ensure that resources are used efficiently and effectively to support students' learning.

African Buffalo Optimization to Curriculum Development

Engaging a programmer to write a programme on the ABO using any programming language for curriculum development shows that the algorithm is effective in:

a. Optimizing learning objectives: ABO can help identify the most important learning objectives to achieve desired outcomes.

b. Curriculum mapping: ABO can create a visual representation of the curriculum, highlighting connections and relationships between topics and helping the teachers to properly map topics that should be treated before the other.

c. Topic sequencing: ABO can determine the optimal sequence of topics to maximize learning outcomes.

d. Content allocation: ABO can allocate content to specific topics or courses to maximize learning outcomes.

e. Assessment alignment: ABO can align assessments with learning objectives, ensuring accurate measurement of student learning.

f. Curriculum evaluation: ABO can evaluate the effectiveness of the curriculum, identifying areas for improvement.

The parameters ABO to be considered in the programming effort are the learning objectives and outcomes, students' needs and abilities, curriculum standards and requirements, teachers' expertise and resources in addition to assessment and evaluation methods (Odili, Noraziah, & Babalola, 2022). Doing the above will show clearly that by applying ABO to curriculum development, educators can create an optimized curriculum that maximizes learning outcomes and prepares students for success

African Buffalo Optimization to Assessment and Evaluation

The ABO algorithm is applicable to pedagogical assessment and evaluation by deliberate application of the algorithm in a given programming language to achieve any or all of the following:

a. Optimizing assessment types: ABO can determine the most effective assessment types (e.g., multiple choice, essay) for each learning objective.

b. Question bank optimization: ABO can optimize question banks to ensure accurate measurement of students' learning.

c. Test construction: ABO can construct tests that maximize accuracy and minimize bias.

d. Grading optimization: ABO can optimize grading criteria to ensure fair and accurate assessment of students' learning.

e. Feedback optimization: ABO can optimize feedback to students, providing actionable insights for improvement.

f. Evaluation methodology: ABO can determine the most effective evaluation methodology (e.g., norm-referenced, criterion-referenced) for each assessment.

In programming with the ABO algorithm to achieve pedagogical assessment and evaluation, the following parameters are to be deliberately programmed: learning objectives and outcomes; students' needs and abilities; assessment standards and requirements, teachers' expertise and resources as well as available facilities bias and fairness.

When the above parameters are properly crafted to ABO code on assessment and evaluation, educators can create optimized assessments that accurately measure students' learning and provide actionable feedback for improvement.

Conclusion

From the foregoing discussion, it is evident that when implemented with an appropriate programming language, the ABO can be promising in enhancing pedagogy by optimizing learning paths and resource allocation, improving curriculum development and assessment, enhancing teachers' support and students' feedback in addition to increasing efficiency and effectiveness in education. As such, by deliberate application of the principles of ABO to pedagogy with careful consideration of the parameters listed, educators can create a more optimized and effective learning environment, ultimately leading to improved students' outcomes and academic success.

However, it is important to point out some technical limitations associated with applying the ABO to enhance pedagogical approaches. One of such is the issue of computational complexity. ABO may require significant computational resources, which can be a challenge for educational institutions with limited budgets or infrastructure. Another is the challenge of data quality and availability. ABO relies on high-quality and relevant data, which may not always be available or accessible in educational settings. Worthy of mention is the challenge of algorithmic transparency. ABO's optimization process may be complex and difficult to interpret, making it challenging for educators to understand and trust the results.

Given the above, we recommend that future research and development of ABO in pedagogy should focus on large-scale implementation and evaluation, integration with existing educational technologies, expansion to diverse educational settings and contexts, continuous refinement and adaptation of the algorithm as well as the investigation of potential ethical and

social implications. We believe that by harnessing the power of ABO, educators can revolutionize the way we approach teaching and learning, thus, creating a brighter future for all students.

Conflict of Interest

The authors assert that no conflict of interest exists in the publication of this manuscript.

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