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RESEARCH ARTICLE

Application of African Buffalo Optimization Algorithm to Cultural Heritage

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ABSTRACT - The cultural heritage of a people defines the people. Cultural heritage refers to the physical and intangible artefacts, traditions and values that are passed down from one generation to another within a community or society, nation or race. Over the years, it has been observed that cultural heritage studies have been bogged by optimization challenges in the areas of resource allocation, route planning and site selection. Providing solutions using the African Buffalo Optimization is the focus of this paper. The relationship between the African Buffalo Optimization which is a swarm optimization technique in computer science and cultural heritage is also examined using the qualitative research method. Using the analytical research method, not an experimental one, to track the relationship between humanities, computer science, Artificial Intelligence, cultural studies and the social sciences, this paper highlights the application of the African Buffalo Optimization to confronting the challenges of cultural heritage and concludes that the algorithm can be applied to optimize various processes, such as digital preservation and conservation, collection management and curation, exhibition and display design, community engagement and participation and cultural heritage tourism management. Such application benefits the global cultural heritage organizations and institutions in several ways. It is, therefore, recommended that the global research community in cultural studies, digital humanities and social sciences should explore the use of swarm optimization techniques, in general, and the African Buffalo Optimization, in particular, to cultural heritage research and scholarship.

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1.0 INTRODUCTION

The increasing development of interdisciplinary researches has led to global focus on seemingly unlikely partnerships in diverse fields of human endeavour [1]. One of such unlikely partnership is the focus of this research. Cultural heritage refers to the physical and intangible artefacts, traditions, and values that are inherited from past generations and are considered important to a community's identity, history, and culture [2]. It encompasses various aspects, including tangible heritage: monuments, historic sites, museums, artefacts, and cultural landscapes; intangible heritage: oral traditions, languages, music, dance, theatre, social practices, and knowledge as well as digital heritage such as digital artefacts, collections, museums, and cultural landscapes [3].

Cultural heritage is important because it shapes identity and sense of belonging of a people, preserves collective memory and history, fosters creativity and innovation, supports education and research, encourages cultural exchange and understanding, contributes to sustainable development and tourism of a community, region, state, nation or race.[4]. Overall, cultural heritage is a vital part of a community's legacy and plays a significant role in shaping its future [5].

On its part, the African Buffalo Optimization (ABO) is a stochastic swarm optimization algorithm developed primarily for effective and efficient search of multimodal search landscapes [6]. In this study, however, attempt is made to see how this computational science algorithm which is gradually gaining global recognition for its efficiency in optimizing complex industrial procedures and processes is applied to the cultural heritage research and scholarship. With computing becoming the bedrock of virtually every knowledge field ranging from medicine to pharmacy, banking, insurance, humanities, administration etc.[7], it is important to explore the possibility of applying the ABO to cultural heritage studies. This is the motivation for this study. Moreover, The ABO algorithm has shown promising results in various optimization problems, but its application to cultural heritage is still a developing area of research, hence this research work.

From literature, it is clear the cultural heritage has the several branches. Cultural heritage encompasses the following
a. Tangible Cultural Heritage:
- Architectural heritage (monuments, buildings, etc.)
- Artistic heritage (paintings, sculptures, etc.)
- Archaeological heritage (sites, artefacts, etc.)
- Ethnographic heritage (traditional crafts, clothing, etc.) [8]

b. Intangible Cultural Heritage:
- Oral traditions and expressions (stories, music, etc.)

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- Social practices and rituals (anniversaries, customs, festivals, etc.).
- Knowledge and practices concerning nature and the universe.
- Traditional craftsmanship and arts [9].

c. Natural Cultural Heritage:
- Natural sites and landscapes (parks, reserves, etc.).
- Biosphere reserves.
- Geoparks [10].

d. Digital Cultural Heritage:
- Digital artefacts and documents.
- Digital art and culture.
- Online archives and libraries [11].

e. Underwater Cultural Heritage:
- Shipwrecks and underwater archaeological sites [12].

f. Industrial Cultural Heritage:
- Industrial sites and landscapes (factories, mines, etc.) [13].

g. Intangible Cultural Heritage in Need of Urgent Safeguarding:
- Endangered languages, music, and crafts [14].

h. Cultural Heritage of Disasters and Conflicts:
- Sites and artifacts related to natural disasters and conflicts [15].

The practice of cultural heritage has been bogged by some challenges that can be solved by the application of a good optimization algorithm like the African Buffalo Optimization, hence this study. Some of those challenges include resource allocation, that is, optimizing resource allocation for preservation and conservation efforts; site selection: identifying optimal locations for cultural heritage sites, museums, or preservation facilities and route planning. Optimizing tourist routes to minimize impact on sensitive cultural heritage sites is a common problem to practitioners in tangible heritage sites. Similarly, the issue of modelling cultural dynamics poses a challenge. Modelling complex interactions between cultural, social, and economic factors is an area that an optimization algorithm can be deployed. The same could be said of heritage diffusion where one can use an optimization algorithm to simulate the spread of cultural heritage across regions and populations. Finally, influence maximization, that is, identifying key factors influencing cultural heritage preservation is another crucial area where the African Buffalo Optimization can be deployed to ensure efficiency and effectiveness.

In view of the above, this study aims at exploring the digitization potentials of cultural heritage research and scholarship from the standpoint of a swarm optimization algorithm, the ABO. The rest of this paper is organized as follows: section two presents a review of relevant literature on the ABO and cultural heritage; section three focusses on cultural heritage and DH, section four examines the place of the ABO in cultural heritage and section five draws conclusion on the study.

2.0 RELATED WORKS

ABO algorithm was designed by Odili and Kahar in 2015 [16]. The algorithm explores the migrant behaviour of African buffalos - a species of wild cows that move from place to place all over the African continent - in search of lush green grass using two main vocalizations: the /waaa/ and the /maaaa/. Using the /waaaa/ vocalization, these African giants, only inferior in size to the African elephants - weighing up to a tonne, the herd of buffalos are summoned to migrate to other locations, possibly due to the over grazed nature of the present location or the presence of predators, in most cases, lions. On the other hand, the buffalos use the /maaa/ vocalization to ask the animals to relax and graze, possibly because to the abundance of pastures or the safety of the locality. The uniqueness of the buffalo migrations is in their capacity for 'democratic election results' as the motivating factor for their movements. Unlike other swarms that have a definite leader that makes crucial decisions for them, the buffalo herd has no leader, rather every adult male participates in the elections that determine their movements [17].

Having stayed in a particular location for a while, it gets to a point when some of the animals get impatient and begin making calls for further exploration using the /waaa/ sounds. Once these individualized calls begin to get louder, it calls attention to the entire herd that it is time for 'election'. The animals tend to move closer to one another forming a kind of parliament for the conduct of the 'democratic election'. Each animal will make its /waaa/ or /maaa/ sound and facing a particular direction. After a couple of minutes, the animals' next movement is usually towards the location faced by a majority of the buffalos. The ABO operates by simulating this democratic procedure in the search for complicated solutions [18].

The ABO, therefore, is a stochastic swarm optimization technique that simulates the harnessing of the incredible search capabilities of a collection of buffalos, sometimes up to 1000 animals in a herd to arrive at a solution that may be impossible for a particular animal to arrive at. It focusses on the collective intelligence of the entire herd to achieve results. The ABO has been applied to a number of theoretical and real-life solutions with amazing outcomes. Examples include the travelling salesman problem, collision avoidance in electric fish, tuning the PID parameters of Automatic Voltage Regulators, optimizing the building of nuclear reactors, global optimization search spaces etc [19]. The amazing outcome from its applications in diverse areas is the motivation for the application of the ABO to cultural heritage in digital humanities research.

2.1 Cultural Heritage

Cultural heritage refers to the physical and intangible artefacts, traditions and values that are passed down from one generation to another within a community or society. It encompasses various aspects, including tangible heritage (such as monuments and historic buildings, artworks and sculptures, archaeological sites and artefacts in addition to museums and collections); intangible heritage(e.g. oral traditions and stories, music and dance, language and dialects, customs and rituals, folklore and mythology etc.); natural heritage (e.g. landscapes and ecosystems, natural monuments and sites) and digital heritage (e.g. digital artefacts and documents, social media and online communities, digital archives and libraries) [20].

Again, cultural heritage can be defined as a social construct that is defined by political, economic and social interests. The discourse on cultural heritage has increasingly questioned the very notion of what cultural heritage is. In the last few decades, cultural heritage has been perceived as an integral part of the national identities. For instance, new models of bottom-up participation and democratic governance are being encouraged through various European Union (EU) flagship initiatives, programs and financial tools [21]. The EU thereby leans on UNESCO and Council of Europe principles of value-based cultural heritage while, at the same time, programs like Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME) which help develop small and medium-sized businesses, are dedicated to the perspective of cultural heritage as capital. The recent academic approach to heritage management is to opt for community-defined values rather than the more usual approach where values are defined through legislation and policy [22].

Cultural heritage derives its meaning through its interaction with people. Therefore, a wide range of values needs to be integrated into planning its policy and practice. Communities need to maintain a primary role in the preservation of local historical heritage and be better acquainted with it. However, local perspectives often differ from the viewpoints of experts on cultural heritage. In this modern era, research and scholarship in cultural heritage is of utmost importance as it helps preserves collective memory and identity, fosters creativity and innovation, supports education and research, encourages cultural exchange and understanding as well as provides economic benefits through tourism and cultural industries [23].

Presently, several efforts are being made, the world over, to preserve, conserve, and promote cultural heritage. Some of these efforts are through UNESCO World Heritage Sites, national and local preservation initiatives, museums and cultural institutions, community-based projects and initiatives, in addition to, digital preservation and online platforms. The preservation of cultural heritage is a vital part of human society [24]. Therefore, its preservation and promotion are essential for building a sense of shared humanity and community.

2.2 Cultural Heritage and Digital Humanities

Cultural heritage and digital humanities are related fields that have been brought together in recent years The Digital Humanities (DH) programmes aim to develop infrastructure and methods for connecting research in the fields of the humanities, computer science, Artificial Intelligence, cultural studies and the social sciences and making the findings in terms of both content and methodology available to the scientific world [25].

Cultural heritage and DH is an interdisciplinary field that combines the study of cultural heritage with digital methods and tools. It involves the use of digital technologies to preserve, analyze, and present cultural heritage materials, such as digital archives and libraries, virtual museums and exhibitions, digital art and cultural installations, social media and online platforms for cultural heritage [26].

Furthering the marriage between DH and cultural heritage, some key areas of focus are digital preservation and conservation, digital curation and metadata, digital scholarship and research methods, digital pedagogy and education, digital cultural heritage and social justice. This emerging field is constantly evolving, with new technologies and methods emerging almost monthly. Some examples of projects and initiatives in this field include Digital Public Library of America, Google Arts & Culture, Europeana, Smithsonian Transcription Centre, Digital Museum of the Southern Jewish Experience etc [27].

2.3 Application of Swarm Optimization to Cultural Heritage

Application of swarm intelligence techniques to cultural heritage is at its infancy. To the best of my knowledge, only three warm techniques, namely Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and the Simulated Annealing (SA) have been applied to specific aspects of cultural heritage. While the work on PSO focusses on marketing archive management; the work deploying ACO is on museum environmental monitoring of cultural relics and the study using the SA examined cultural and creative product design [28]. Our research discusses the several aspects of cultural heritage, thus providing a solid theoretical framework upon which many more research efforts on cultural heritage using swarm optimization techniques shall build upon.

From the foregoing, it could be observed that applying swarm optimization to cultural heritage preservation is an innovative approach that leverages collective intelligence to solve complex problems. This effort reveals that swarm intelligence algorithms, such the PSO and the ACO have proven effective in solving complex optimization problems in cultural heritage preservation, like resource allocation and scheduling. Moreover, the application of swarm optimization algorithm provides flexibility and adaptability to cultural studies research. These algorithms can adapt to changing conditions and constraints, making them suitable for dynamic cultural heritage environments. Similarly, it leads to improved decision-making. Swarm optimization can provide decision-makers with optimal solutions, enabling informed choices about preservation strategies and resource allocation.

In spite of those listed advantages, the application of swarm optimization to cultural studies scholarship still has limited applications. Despite its potential, swarm optimization has limited applications in cultural heritage preservation, hence this study. Again generally, speaking swarm optimization techniques are rather complex to non-experts. Swarm optimization algorithms can be complex to implement and require significant computational resources, which may limit their adoption in cultural heritage contexts. Finally, there is a need for standardized evaluation metrics to assess the performance of swarm optimization algorithms in cultural heritage preservation.

The choice of optimization method depends on the specific cultural heritage problem, considering factors like optimization performance, computational efficiency, robustness, and flexibility. So far, ABO shows promise, but further research is needed to fully understand its strengths and limitations compared to other optimization methods.

2.4 Digital Humanities in Cultural Heritage

DH in Cultural Heritage refers to the intersection of digital technologies, humanities research, and cultural heritage preservation. It involves the application of digital methods and tools to preserve and conserve cultural heritage artefacts and sites, analyze and interpret cultural heritage data, represent and exhibit cultural heritage in digital environments, engage and interact with cultural heritage through digital media and foster collaboration and knowledge sharing among cultural heritage stakeholders [30].

Consequently, some key areas of DH in cultural heritage include digital curation and preservation, digital museums and exhibitions, cultural heritage informatics, digital cultural heritage pedagogy, community engagement and participation, digital cultural heritage ethics, virtual and augmented reality applications, digital storytelling and narrative, cultural heritage data analytics as well as digital cultural heritage policy and governance [31].

In view of the foregoing, DH in cultural heritage has the potential to increase accessibility and engagement with cultural heritage, enhance preservation and conservation efforts, support innovative research and scholarship, foster global collaboration and knowledge sharing, promote cultural heritage education and awareness, support community-led initiatives and cultural heritage management, encourage ethical and responsible use of cultural heritage data, develop new forms of cultural heritage representation and exhibition, support cultural heritage tourism and sustainable development as well as advance the field of cultural heritage studies [32]

However, despite the potential of digital humanities, many cultural heritage institutions face challenges in making their digital collections accessible to diverse audiences, including those with disabilities. This tendency tends to hinder scholarship to the application of DH to cultural studies. Again, DH projects often rely on short-term funding, which can make it challenging to ensure the long-term sustainability of digital collections and platforms. Lastly, the digital divide between institutions with adequate resources and those without can exacerbate existing inequalities in access to cultural heritage, hence the need to promote the exploration of cultural studies using as many digital tools as possible. This is one of the motivations for this study.

3.0 METHODS AND MATERIAL

The ABO algorithm is presented:

Listing 1. ABO Algorithm

1. Initialization: randomly place buffalos to nodes at the solution space;
2. Update the buffalos' exploitation using Equation:
3. $m_k' = m_k + lp1(bg - w_k) + lp2(bp_k - w_k)$

   where m_k and w_k represents the exploitation and exploration moves respectively of the k^{th} buffalo(k=1, 2…. N); $lp1$ and $lp2$ are learning factors; bg is the herd's best fitness and bp, the individual buffalo's best location
4. Update the location of buffalos using the Equation:
5. $w_k' = \frac{(w_k + m_k)}{\lambda}$
6. Is bg_{max} updating? Yes, go to 5. If no, go to 2
7. If the stopping criteria is not met, go back to algorithm step 2, else go to 6

```
8.   Output best solution.
```

Similarly, the algorithm's flowchart is presented:

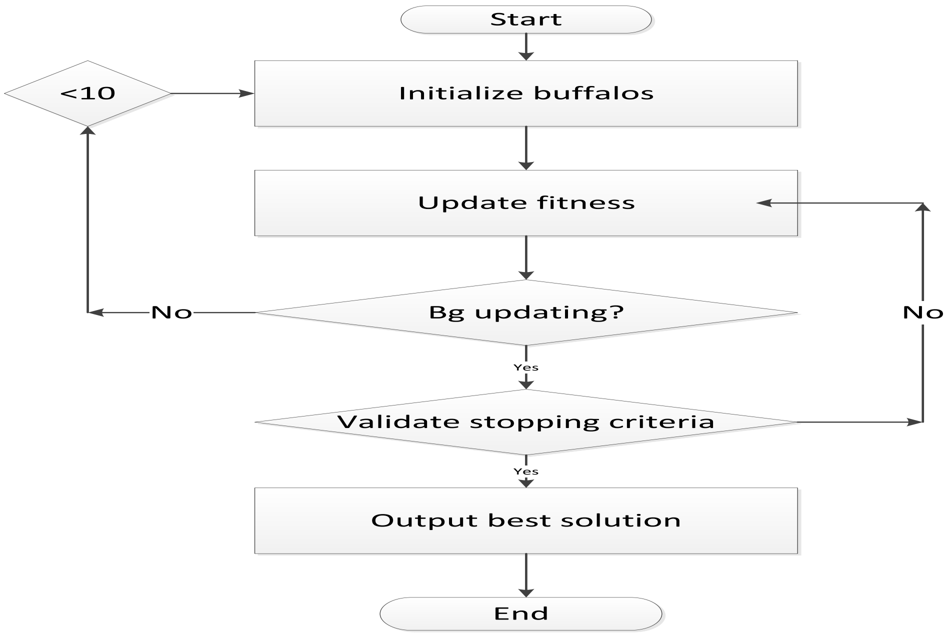

Figure 1: ABO flowchart

Following from the above, the ABO's solution steps to cultural heritage is presented:

a. Problem Formulation

i. Define the optimization problem: Identify the specific cultural heritage preservation problem to be optimized (e.g., optimizing conservation efforts, classifying artifacts, minimizing costs, maximizing preservation effectiveness).
ii. Determine the objective function: Develop a mathematical representation of the optimization problem (e.g., minimize costs = minimize (preservation costs + maintenance costs)).
iii. Identify constraints: Determine the constraints that need to be satisfied (e.g., limited resources, environmental factors budget constraints, resource constraints).

b. Data Collection and Preprocessing

i. Gather relevant cultural heritage data (e.g., historical records, artifact descriptions).
ii. Convert data into suitable format for ABO.

b. Data Collection and Analysis

i. Collect relevant data: Collect relevant data on cultural heritage preservation costs, effectiveness, historical records, artifact descriptions and other relevant factors.
ii. Clean and preprocess data (e.g., handling missing values, normalization).
iii. Analyze the data: Analyze the data to identify trends, patterns, and insights that can inform the optimization process.
iv. Use the data to validate the results: Use the data to validate the results of the African Buffalo Optimization Algorithm and ensure that they are realistic and effective.

c. African Buffalo Optimization Abridged Algorithm

Listing 2. ABO Abridged Algorithm

```
1. Initialize the population: Initialize a population of African buffalos with random
   positions and velocities.
2. Evaluate the objective function: Evaluate the objective function for each buffalo
   in the population.
3. Update the /waaa/ and /maaa/ locations: Update the locations of the buffalos based
   on the African Buffalo Optimization Algorithm's update rules.
4. Repeat the process: Repeat the process until a stopping criterion is met (e.g.,
   maximum number of iterations).
```

d. Application to Cultural Heritage

i. Map the problem to the algorithm: Map the cultural heritage preservation problem to the ABO framework.
ii. Use the algorithm to find optimal solutions: Use the African Buffalo Optimization Algorithm to find optimal solutions to the cultural heritage preservation problem.
iii. Evaluate the results: Evaluate the results and compare them to other optimization algorithms or baseline solutions.

e. Implementation

i. Develop a software implementation: Develop a software implementation of the ABO for cultural heritage preservation.
ii. Test the implementation: Test the implementation to ensure that it is working correctly and producing optimal solutions.
iii. Deploy the implementation: Deploy the implementation in a real-world setting to optimize cultural heritage preservation.

f. ABO Algorithm Implementation

Listing 3. ABO Algorithm Implementation

```
1. Initialize ABO parameters:
    -   Population size (N)
    -   Number of iterations (T)
    -   No of buffalos
   For the purpose of this study, the ABO parameters are
    -   int buffalo herdSize = 20;
    -   int  max iterations    = 100;
    -   double buffalo /waaa /= 0.2;
    -   double buffalo maaa   = 0.1

2. Generate initial buffalo population:
    -   Randomly initialize N buffalo (solutions)
    -   Evaluate fitness using objective function
3. Apply ABO operators:
    -   Selection: Select best buffalo (elitism)
4. Update buffalo population:
    -   Replace least fit buffalo with new offspring
    -   Evaluate fitness and update best solution
```

4.0 APPLYING THE AFRICAN BUFFALO OPTIMIZATION TO CULTURAL HERITAGE

African Buffalo Optimization (ABO) is a metaheuristic algorithm inspired by the social behaviour of African buffalo herds. In the context of cultural heritage, ABO can be applied to optimize various processes, such as digital preservation and conservation, collection management and curation, exhibition and display design, community engagement and participation and cultural heritage tourism management. ABO's unique ability which places it above some other optimization algorithms is crucial here. Some of the ABO advantages include its uncommon search ability to track global optimization. ABO's ability to avoid local optima and converge to global optima is crucial in cultural heritage research. Again, the algorithm's robustness is another advantage. ABO's resilience to noise and uncertainty in cultural heritage data is found to be very useful. Moreover, the algorithm's flexibility and robustness enhance adaptability to diverse cultural heritage problem domains.

As such, ABO helps optimize cultural heritage processes by:

i. Identifying optimal solutions for preserving and conserving cultural heritage artifacts
ii. Finding the most efficient ways to manage and curate collections
iii. Designing exhibitions and displays that maximize engagement and cultural understanding
iv. Developing community-led initiatives and participatory approaches
v. Managing tourism flows and promoting sustainable cultural heritage tourism

Let us, at this juncture, consider each of the above five points in some details.

4.1 Identifying optimal solutions for preserving and conserving cultural heritage artefacts using the African Buffalo Optimization algorithm

The ABO algorithm is applied to identify optimal solutions for preserving and conserving cultural heritage artefacts by modelling the problem as an optimization problem. The algorithm can be used to determine the optimal storage conditions (temperature, humidity, etc.) for artefacts, identify the most effective conservation treatments and materials, optimize the placement and arrangement of artefacts in storage or exhibition spaces, develop efficient cleaning and maintenance schedules, select the best materials and techniques for restoration and repair, optimize the use of resources (time, budget, personnel) for conservation efforts, identify the most effective strategies for preventing damage and deterioration and develop personalized conservation plans for specific artefacts or collections

To achieve the above, the ABO algorithm can be applied in various ways, such as through simulating different conservation scenarios and evaluating their effectiveness, identifying the optimal combination of conservation treatments and materials, optimizing the allocation of resources for conservation efforts, predicting the behaviour of artefacts under different environmental conditions and identifying potential risks and developing strategies to mitigate them

Concomitantly, by using the ABO algorithm, cultural heritage institutions and conservators can make data-driven decisions and develop effective conservation strategies to ensure the long-term preservation and protection of cultural heritage artefacts. Therefore, by applying ABO to cultural heritage, researchers can harness the power of collective intelligence and social behaviour of the African buffalos to protect, preserve, and promote our cultural heritage for future generations.

4.2 ABO for finding the most efficient ways to manage and curate collections

The ABO algorithm is applied to find the most efficient ways to manage and curate collections in cultural heritage institutions by optimizing various aspects of collection management, such as the collection cataloguing and documentation. object classification and categorization, storage and inventory management, exhibition and display planning, conservation and restoration prioritization, digitization and digital preservation, access and accessibility management, collection development and acquisition, deaccessioning and disposal as well as the collection evaluation and assessment of curate collection management strategies

Applying ABO helps optimize the above-listed processes through the identification of the most efficient cataloguing and documentation methods, development of optimal classification and categorization systems, determination of the best storage and inventory management strategies, creation of effective exhibition and display plans, prioritization of the conservation and restoration efforts, optimization of the digitization and digital preservation workflows, management of the access and accessibility for diverse audiences, development of strategic collection development and acquisition plans, identification of optimal deaccessioning and disposal strategies and the efficient evaluation and assessment of collection significance and value.

Following from above, it may be safe to conclude that applying ABO to collection management and curation, cultural heritage institutions can:

i. Improve collection accessibility and visibility
ii. Enhance collection preservation and conservation
iii. Streamline collection management processes
iv. Increase efficiency and productivity
v. Support data-driven decision making
vi. Foster collaboration and knowledge sharing
vii. Promote cultural heritage education and research
viii. Support community engagement and outreach
ix. Advance collection management best practices
x. Ensure long-term collection sustainability.

4.3 Designing exhibitions and displays that maximize engagement and cultural understanding using the ABO

The ABO algorithm is applied to design exhibitions and displays that maximize engagement and cultural understanding by optimizing various aspects of exhibition design in cultural heritage. These are achieved through using the algorithm for the exhibition layout and spatial planning, object selection and grouping, labelling and interpretation, interactive and immersive experiences, visual and multimedia displays, lighting and sound design, visitor flow and navigation, accessibility and inclusivity, storytelling and narrative development, evaluation and feedback mechanisms etc.

ABO helps optimize the above aspects of cultural heritage by identifying the most engaging and culturally-relevant objects and stories, developing optimal exhibition layouts and spatial designs, creating effective labelling and interpretation strategies, designing interactive and immersive experiences that foster cultural understanding, optimizing visual and multimedia displays for maximum impact, developing lighting and sound designs that enhance the visitor experience, improving visitor flow and navigation, ensuring accessibility and inclusivity for diverse audiences, developing compelling storytelling and narrative approaches, evaluating and refining the exhibition design based on visitor feedback and behaviour etc.

Cultural heritage institutions are able to benefit from applying ABO to exhibition design through increased visitor engagement and satisfaction, enhanced cultural understanding and empathy, improved exhibition accessibility and inclusivity, supporting diverse audience engagement, the fostering of community collaboration and co-curation, development of innovative and interactive exhibition experiences, the encouragement of visitor participation and feedback, supportive cultural heritage education and research, advanced exhibition design best practices as well as ensure exhibitions that are both meaningful and memorable.

4.4 Developing community-led initiatives and participatory approaches using the ABO

The ABO algorithm is applied to develop community-led initiatives and participatory approaches in cultural heritage management by identifying community needs and preferences, optimizing community engagement and participation strategies, developing inclusive and representative decision-making processes, enhancing community capacity and skill development, fostering collaborative partnerships and networks, creating culturally responsive and relevant programs, ensuring accessibility and inclusivity in cultural heritage initiatives, developing community-led conservation and preservation efforts, supporting community-based cultural heritage research and documentation, evaluating and refining community-led initiatives based on feedback and outcomes etc. [33].

ABO can help optimize the above listed processes by effectively and efficiently analyzing community data and feedback, identifying optimal community engagement strategies, developing effective community outreach and participation methods, enhancing community leadership and capacity building, fostering collaborative partnerships and networks, creating culturally responsive and relevant programs, ensuring accessibility and inclusivity in cultural heritage initiatives, developing community-led conservation and preservation efforts, supporting community-based cultural heritage research and documentation in addition to defining community-led initiatives based on evaluation and feedback [34].

Therefore, through careful application of the ABO algorithm to community-led initiatives, cultural heritage using appropriate programming languages such as Java, MATLAB, C++, C# etc. cultural heritage institutions can:

i. Increase community engagement and participation
ii. Enhance cultural heritage management and preservation
iii. Support community development and capacity building
iv. Foster collaborative and inclusive decision-making processes
v. Develop culturally responsive and relevant programs
vi. Ensure accessibility and inclusivity in cultural heritage initiatives
vii. Support community-based research and documentation
viii. Advance community-led cultural heritage management best practices
ix. Ensure cultural heritage initiatives are community-driven and sustainable
x. Strengthen community relationships and partnerships etc.

4.5. Managing tourism flows and promoting sustainable cultural heritage tourism using the ABO

The ABO algorithm is applied to manage tourism flows and promote sustainable cultural heritage tourism by optimizing tourist routes and itineraries, managing tourist numbers and capacity, identifying optimal tourist seasons and scheduling, developing sustainable transportation systems, enhancing cultural heritage interpretation and education, promoting community engagement and participation, supporting local economic development and entrepreneurship, ensuring cultural heritage preservation and conservation, developing inclusive and accessible tourism infrastructure, evaluating and refining tourism management strategies.

ABO is helpful in optimizing the above processes through analyzing tourist data and behaviour, identifying optimal tourism management strategies, developing effective tourism marketing and promotion, enhancing tourist experience and satisfaction, supporting community-led tourism initiatives, ensuring cultural heritage protection and preservation, promoting sustainable tourism practices, fostering collaboration among tourism stakeholders, developing resilient and adaptable tourism systems, refining tourism management strategies based on evaluation and feedback.

Cultural heritage institutions, by applying ABO to tourism management, are able to increase tourism revenue and economic benefits, enhance cultural heritage preservation and conservation, support community development and engagement, promote sustainable and responsible tourism practices, improve tourist experience and satisfaction, ensure inclusive and accessible tourism infrastructure, foster collaboration and knowledge sharing among tourism stakeholders, advance sustainable cultural heritage tourism best practices, ensure long-term cultural heritage preservation and tourism sustainability and support the United Nations' Sustainable Development Goals (SDGs) as well as other national development goals etc.

5.0 RESULTS AND DISCUSSION

Applying ABO to cultural heritage leads to efficient search: Being an optimization algorithm, the ABO reduces search time compared to exhaustive search methods. This saves time of the cultural expert’s time leading to better saving of crucial man-hours. Again, applying the algorithm to cultural heritage results in the generation of diverse solutions to cultural heritage patterns and relationships. ABO generates diverse solutions, revealing new cultural heritage patterns and relationships.

Furthermore, hidden patterns are revealed when the algorithm is applied. ABO uncovered hidden patterns in cultural heritage data, revealing new insights into historical events and cultural practices. In addition, ABO identifies Influential factors in cultural heritage development. ABO identifies key factors influencing cultural heritage development, such as geographical location and social dynamics.

Finally, the application of swarm intelligence algorithm, such as the ABO enhances cultural exchange: ABO detects evidence of cultural exchange between different communities, shedding light on historical trade and migration patterns.

The above discussions highlight the robustness of the ABO as an efficient optimization search algorithm. ABO's adaptive search strategy effectively navigated complex cultural heritage data. Similarly, it is a further proof of the algorithm’s scalability potentials. ABO handles large datasets, demonstrating potential for application to extensive cultural heritage collections. Finally, the use of the algorithm in cultural heritage studies underscores the algorithm’s interpretability: ABO's results provide actionable insights into cultural heritage patterns and relationships.

6.0 CONCLUSIONS

The ABO algorithm is applicable to various aspects of cultural heritage management, including identifying optimal solutions for preserving and conserving cultural heritage artifacts, finding the most efficient ways to manage and curate collections, designing exhibitions and displays that maximize engagement and cultural understanding, developing community-led initiatives and participatory approaches and managing tourism flows and promoting sustainable cultural heritage tourism.

In the context of cultural heritage, ABO is applied to optimize various processes, such as digital preservation and conservation, collection management and curation, exhibition and display design, community engagement and participation and cultural heritage tourism management.

Proper application of the ABO helps optimize cultural heritage processes through proper identification of optimal or near optimal solutions for preserving and conserving cultural heritage artefacts, explicate the most efficient ways to manage and curate collections, assist in properly designing exhibitions and displays that could maximize engagement and cultural understanding, develop community-led initiatives and participatory approaches in cultural heritage management as well as assist in the efficient management of tourism flows, thus, promoting sustainable cultural heritage tourism within a locality, nation or even globally.

However, the application of the African Buffalo Optimization algorithm to cultural heritages has a few challenges. Some of which are the need to properly resolve the algorithm’s computational complexity arising from computational requirements for large-scale problems. This could be resolved through proper parameter-tuning where the parameter-less version is not suitable. Finding optimal ABO parameters for specific cultural heritage problems may pose a challenge to amateur programmers too. Finally, the choice of a appropriate programming language among the over a thousand programming language available globally, today, may also pose a challenge.

Overall, the major contributions of this study to the field is the discovery of ABO’s capacity to optimizing preservation strategies of cultural studies: The ABO Algorithm helps identify most effective preservation methods, allocate resources efficiently and streamline conservation efforts. Moreover, the algorithm enhances cultural heritage management: By applying this algorithm, cultural heritage managers can make data-driven decisions, prioritize projects and optimize resource allocation. Further, the algorithm improves decision-making in cultural studies management The algorithm's ability to solve complex optimization problems aids in making informed decisions about cultural heritage preservation and management. As such, this study contributes to developing more efficient methods for cultural heritage preservation, resource allocation, conservation planning and decision-making support systems

In any case, in view of the above listed benefits, the author recommends the application of the ABO and swarm intelligence systems, in general, to cultural heritage research and scholarship. It is hoped that this this paper will motivate other researchers to explore the use of swarm optimization algorithms in cultural heritage research and digital humanities.

AUTHORS CONTRIBUTION

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CONFLICT OF INTEREST

No conflict of interest exists in the publication of this paper.

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