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Application of Firefly Optimization Algorithm and Mobile Edge Computing in the Ice and Snow Sports Industry

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Abstract:

Due to the increasing popularity of ice and snow activities, there is a high demand for efficient resource management, fast data processing, and personalized user experiences. As a result of user interactions, Internet of Things (IoT) sensors, and wearable devices, the ice and snow sports industry processes large amounts of data with minimal latency, exceptional reliability, and data security. Standard cloud computing architectures are inadequate for these jobs due to data centralization, bandwidth constraints, and network latency. In this study, we introduce MEC-FOA, a new framework. It combines the Firefly Optimization Algorithm (FOA) with Mobile Edge Computing (MEC). The primary goals are customer satisfaction and efficiency in ice and snow activities. To maximize offloading tasks and resource allocation in an MEC environment, this technique adjusts the FOA to consider variables such as energy consumption, process delay, and network connectivity. Wearable sensors and Internet of Things devices gather real-time data on the performance of athletes, ambient factors, and equipment status, while MEC nodes are positioned strategically near training facilities and competition locations. To distribute jobs efficiently, the FOA considers processing needs and the current loads on MEC nodes and modifies the brightness and attraction of fireflies, which stand in for tasks. The suggested method offers real-time insights, performance metrics, and immersive experiences to improve things for everyone. The suggested method enabled real-time decision-making improvements by decreasing processing overhead and delay. The user experience A novel framework, MEC-FOA, is presented in this paper. It integrates Mobile Edge Computing (MEC) with the Firefly Optimization Algorithm (FOA). Improving efficiency and satisfaction for ice and snow sports consumers is the target. was significantly improved by quicker processing and response times of data.

Keywords: Mobile Edge computing, Firefly Optimization Algorithm, Ice and Snow Sports Industry.

1. Introduction

Several factors, such as increased media attention, increased attendance at winter sports events, and a general uptick in interest in health and fitness worldwide, have contributed to the ice and snow sports industry's spectacular comeback in recent years. As a form of recreation and health education, ice and snow sports have grown in popularity in recent decades. A wide range of physically demanding pursuits have been engaged in, including shooting, jogging, leaping, strolling, and dancing [1]. There is substantial social value in the ice and snow sports growth in China's middle class. Because ice and snow sports are so demanding and resource-intensive, most participating athletes are members of the social elite [2]. An explosion in the number of people using smartphones equipped with intelligent terminals has occurred as a direct result of the proliferation of cloud computing and other mobile communication technologies [3]. A difficult computing problem is dealing with the enormous amounts of data Smart Mobile Devices (SMDs) collect. To solve this issue, researchers are using Edge Computing, a new paradigm in computation. Reducing computing latency and energy usage can be achieved by bringing computing resources nearer to the end devices [4]. MEC provides computational and storage resources to end users on the go. Deploying MEC resources on mobile networks near end users is the plan. [5]. It is possible to handle computational activities in MEC systems with an MEC server. Because the MEC server is physically adjacent to mobile users and typically has enough processing power, offloading can significantly cut the user's computation time and energy consumption [6].

A smart wearable gadget is an electronic accessory that is both portable and designed to be worn on the body. An operation unit is also a part of a wearable device; it is set up to accept instructions for specific operations from another unit and carry them out [7]. One of the most significant ways to tell if an ice and snow athlete is top-notch is by seeing how well they demonstrate the intricate movements of their lower body. This skill relies heavily on the athlete's dexterity with his or her lower extremities. [8]. One approach to solving difficult problems in engineering and other disciplines is optimization. Finding, within a clearly defined research area and subject to varying constraints, the cost function's optimal value is what optimization is all about [9]. Nowadays, the Firefly Algorithm is a key component of Swarm Intelligence, which is used in several optimization and engineering domains. The firefly with the maximum intensity and the minimum distance is the ideal answer to an objective function. [10]. When it comes to engineering, firefly algorithms have been widely used for their ability to achieve maximum efficiency. The program takes its cues from nature; for example, every firefly has an exceptionally bright body that draws in other fireflies nearby [11].

This study presents a fresh strategy that combines FOA and MEC to address the specific problems encountered by the ice and snow sports sector. Our proposed MEC-FOA solution combines the best features of both approaches to improve the operational effectiveness of sports facilities, allocate resources more efficiently, and give fans, players, and coaches access to real-time performance data analysis, augmented reality (AR) experiences, and fully immersive training environments.

The main contribution of this paper is

- It uses FOA to improve the distribution of tasks among edge devices, which leads to faster processing and less latency.
- By combining MEC with sensor networks, it is possible to interpret data from ice and snow sports facilities in real time.
- The proposed MEC-FOA uses predictive analytics to optimize maintenance scheduling, which improves operational efficiency and ensures that outstanding ice and snow sports venues are always available.

Combining the FOA with MEC greatly improves the ice and snow sports business. This is because it optimizes work allocation and resource usage. FOA guarantees dynamic allocation of resources in MEC contexts by improving energy efficiency and current information manufacturing, hence lowering latency. In addition to facilitating real-time augmented reality experiences, this synergy enhances the effectiveness of operations and upkeep management in sports facilities, allowing sophisticated applications such as performance analysis. The proposed MEC-FOA strategy improves decision-making and resource optimization to run large sports complexes more smoothly, which benefits users and gives coaches and athletes more information.

2. Literature review

Using a three-dimensional model of ice and snow, Jin, Y., and Li, B. [12] developed a path-planning algorithm. Much research has been done on the path-planning approach to snow and ice transportation using the MNN (Multiclass Neural Networks) algorithm. The MNN method is employed for thorough evaluations and analyses. Based on the results, ice and snow route planning systems that use MNN algorithms are highly feasible, have a great forecasting effect, and have very accurate data, all of which should increase the success rate of ice and snow path planning. Nevertheless, the research disregards the directional capturing efficiency and the possible influence of inaccuracy in favour of a path-planning approach to ice and snow movement.

Li, X. et al. [13] researched optimising the ice and snow sports industry's supply chain through AI and communication amongst sensor networks. In the section devoted to the methodology, the article delves into the design of sensor nodes and networks. It then describes how the research acquired and analyzed its experimental data by utilizing the adaptability of data acquisition structures and the ongoing surveillance of wireless sensor networks. The article concludes by introducing the particular topics of AI about the ice and snow sports industry. The algorithm incorporates the grey relationship analysis approach. The sports industry has a lot of untapped potential for growth and enough internal impetus for expansion, as this occurrence demonstrates. The modern service economy and society rely on it heavily, which is a key factor in their growth.

A real-time imaging processing framework based on convolutional neural networks called CNN-RTIPF was introduced by Jiang, Y., and Bao, C. [14] to classify every single ice hockey move. To learn, convolutional neural networks (CNNs) document and compare each activity to a training set. These gathered images are processed in real-time by an AI system with a human emphasis. They compared the expected images with the developed set of photos and the probability calculations to obtain correct categorization. Results from simulations demonstrated that the suggested CNN-RTIPF enhanced sensitivity, accuracy, and classification ratio in real-time image classification. The proposed CNN-RTIPF was found to be dependable through dependability optimization. Thanks to CNN-RTIPF, we no longer have to worry about missing a single player's move.

To uncover the link between winter activities and sports culture, Han, C. [15] suggested using associated principles in accessibility big data. There are easier and more effective ways, and this one is both. The results of the experiments conducted in this paper show that the improved Apriori algorithm achieves an operational efficacy of about 90%, in contrast to the 50% operational effectiveness of the traditional Apriori approach. According to research using the Apriori algorithm, snow sports and sports culture are symbiotic, meaning they complement and enhance one another.

Commitment sports service commodities were used as consumption objects in an organic system created by Zhang, T., and Wang, W. [16]. By concentrating on the demanding condition of participation sports consumers, they hoped to gain insight into the reasons and requirements of citizens' involvement in sports consumption and offer businesses entrance points for building marketing tactics. Using a group identification algorithm to ascertain sports consumer involvement, this study's findings are not particularly relevant to real-life situations. Examining the micro-consumption habits of the ice and snow sports industry is the main goal of consumer behaviour management.

Chen W. et al. [17] examined the features of the winter sports industry growth and used the SWOT-AHP framework to assess the state of the sector in Zhangjiakou. This article contends that the integrated industrial growth pattern is the best option to promote the ice-snow culture business in Zhangjiakou. The statistical analysis lacks comprehensiveness due to the constraint of data access. Furthermore, there is a lack of relevant domestic academic literature and research on ice-snow tourism and the Winter Olympics because these themes are still relatively new in China.

Zhang, S. [18] analyzed potential pre- and post-competition scenarios and ways to turn figure skating into a full-fledged industrial chain. This paper seeks to integrate meta-universe technology with the sport to investigate the viability of technologically transforming figure skating as a sport. With the help of meta-universe technologies like blockchain, the Internet of Things, and human-computer interaction, figure skating can overcome challenges with limited venues and unclear scoring standards. This makes the competition more transparent and fairer. Science and technology constantly evolve to suit the growing demand from all aspects of life.

Moody, S. [19] built a digital twin scene as a ski venue based on the foundation of digital twin technology. It is based on the intrinsic requirements of the country's sports industry's high-quality development and matching individualized consumer needs. The driving forces are the goal of creating ski apparel with the customer's experience in mind and the intelligent construction and service efficiency of ski resorts. business scenarios, simulation-based models for managing and operating ski resorts, intelligent decision-making systems for skiing, and early warning linkage for skiing-related decisions. An essential subject for the country's ice and snow industry's development is how to "activate" the skiing scene through the improved application of critical digital twin technologies.

Using the BP neural network and wireless communication technologies, Li, J et al. [20] optimized the ambient characteristics of the ice and snow sports sites. Indoor ice and snow sports venues require careful consideration of several factors. Natural ice rinks include temperature monitoring, audience health monitoring, building safety in relation to weather conditions, and disaster detection and alert. With the help of wireless communication technologies and BP neural network, the suggested approach optimizes the ambient factors of the ice and snow sports destinations. Using a convolutional BP neural network, this study analyzed the environmental factors affecting the chosen sport. The environmental variables of the chosen sports must still be evaluated, though.

Using the TripAdvisor platform as a starting point, Zhang, Y et al. [21] extracted ice and snow sports review text from the web, processed the data, applied the TF-IDF method to quantify consumer comment attributes, investigated potential themes using the LDA model, and lastly builds an emotion classification model to analyze consumers' emotions. Their emotional bias will be better understood, and they can offer reference proposals for the country's decision-making and economic development in the ice and snow. It was unable to handle the ice and snow market's massive supply.

To accomplish the goals of information and digitalization, Du, Y., et al. [22] delves more into the topic of network skill's application to sports event information management, specifically how to effectively capture data from sporting events and put it to use. In addition, we want to learn how sporting events have changed in the age of the IoT. IoT edge computing is used to study how sporting events affect the host city's economy and culture. We demonstrate the method's efficacy and ideal purpose by weighing the pros and cons of the conventional centralized optimization approach, which we then use to provide a set of performance metrics and utility functions. Research on the use of sports event legacy has not been conducted due to a lack of resources.

3. Proposed Methodology

a. Dataset Explanation

Data about a sporting event, most likely the Olympic Games or another comparable massive tournament, is available in CSV (Comma-Separated Values) files. These files contain a plethora of information for many uses. Information on those who participated and their coaches may be found in the files athletes.csv and coaches.csv. For the men's and women's curling and hockey events, this can find comprehensive results in the curling_results.csv and hockey_results.csv files. Individual hockey player statistics are also available in the hockey_players_stats.csv file. While the events are listed in the entries_discipline.csv file, the athletes' entries are categorized according to their sports. The CSV file details everything that happened, including the prerequisites. The medals.csv file details the medal-winning athletes, whereas the medals_total.csv file compiles the total number of medals won by each nation. In addition, the technical officials.csv file contains details about the judges and referees who were part of the event's technical staff. Research, analysis, and insights into the event's many facets, including medal distributions, athlete performances, and the dynamics of individual sports, can be obtained from this extensive dataset.

b. Firefly Optimization Algorithm

The FA is a very effective metaheuristic approach for optimization issues. This program, which is based on an adaptation by Yang, uses three distinct aspects of firefly flashing behaviour:

- All fireflies are of the same gender.
- The intensity of flashing can influence the flashing behaviour of any firefly. The less brilliant fireflies will swarm the more brilliant ones.
- In optimization problems, the objective function can change fireflies' brightness depending on whether the problem is a maximum or minimum optimization problem [23].

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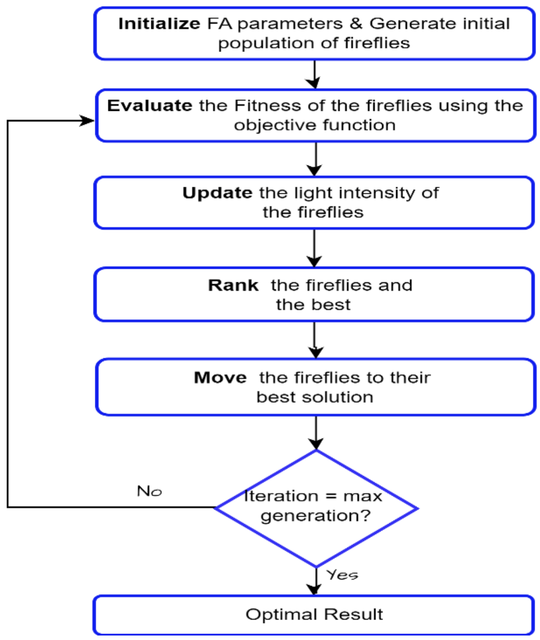

Fig 1. Process of FOA

Fig 1 shows the FOA flow chart. The FOA randomly assigns fitness values and placements to a population of fireflies. The light variance in intensity is subsequently defined, with higher intensities indicating better solutions. In accordance with the distances they travel and light intensities, the algorithm determines the attractiveness of each firefly to brighter fireflies. Based on their attractiveness and a randomness element, each firefly travels towards the brighter one. After assessing its suitability, a firefly will change its location if it finds a more suitable one. The process terminates if a termination requirement is satisfied, such as the maximum number of iterations or good solution. At last, the method returns the firefly population's optimal answer.

c. Application of FOA in the Ice and Snow Sports Industry

The ice and snow sports sector may be able to use the FOA, especially in event scheduling, venue planning, and equipment design. Here are a few ways FOA could be used in this field:

Equipment design optimization:

The process of designing ice skates, skis, or snowboards with an eye on maximizing their performance in terms of aerodynamic design, weight distribution, and mechanical attributes. Optimizing the shape and materials of safety equipment (helmets, pads, etc.) ensures that it is as safe and comfortable as possible. Improving the functionality of snow grooming and ice resurfacing machinery.

Venue planning and design:

Layout optimization involves designing and constructing ski resorts with topography, accessibility, and environmental effects in mind. This includes the location of lifts, trails, and services. When designing and building ice rinks, whether indoor or outdoor, consider aspects like energy efficiency, air circulation, and security.

Event scheduling and logistics:

Making the most efficient use of venue capacity, broadcast window, and athlete availability while planning the schedule of winter sports events. Streamlining logistics and transportation for major events, involving participants, coaches, and equipment, such as the Winter Olympics and World Championships.

For FOA to work, precise criteria must be used to set objective tasks, such improving performance metrics or decreasing energy use. Variables that can be changed, or "decision variables," include things like course material, venue, and technical requirements. Important aspects that affect FOA's efficacy include the availability of reliable data or investigation, the complexity of the problem, the precision of the target function's formulation, and the presence of domain specialists who can help with proper simulations and result interpretation.

d. Application of MEC in the Ice and Snow Sports Industry

Ice and snow activities are perfect for MEC because of its low latency, effective data handling, and real-time processing. The capacity of edge nodes to scan video from various cameras, assess methods, performance measures, and activities, and then give quick feedback to coaches and athletes is a significant usage of current time footage evaluation in training and performance monitoring. The low-latency AR and VR experiences offered by MEC could be advantageous for coaches, players, and spectators alike. These experiences feature fully immersive content with real-time data displays and simulated replays, which enhance the overall experience.

In addition, by evaluating data from various sensors to regulate crowds, analyze energy usage, and monitoring infrastructure, MEC assists with site and managing events efficiency. This ensures that operations run smoothly and that everyone is safe. Processing data from built-in sensors also facilitates the use of linked devices and wearables by way of real-time feedback, analysis of performance, and prevention of injuries. Regarding logistics, safety, and venue monitoring, MEC allows for low-latency management and coordination of self-driven cars and drones. Furthermore, it enhances streaming quality and improves live streaming by processing and storing data at edge nodes, which reduces network congestion.

e. The proposed MEC-FOA in the Ice and Snow Sports Industry

The proposed MEC-FOA method is used in the ice and snow sports industry to improve operations, performance, and user experiences. Fig 2 shows the overall process of the proposed MEC-FOA method. By applying the proposed MEC-FOA framework, the ice and snow sports business aims to optimize resource allocation and enhance customer experience through enhanced real-time data processing. Data from ski areas and sports facilities infrastructure, user preferences, information about past and present weather, details about sporting events, data collected from IoT sensors at venues, and historical meteorological data are all inputs. FOA begins by setting up some initial values for variables like population size, attractiveness, and movement dynamics.

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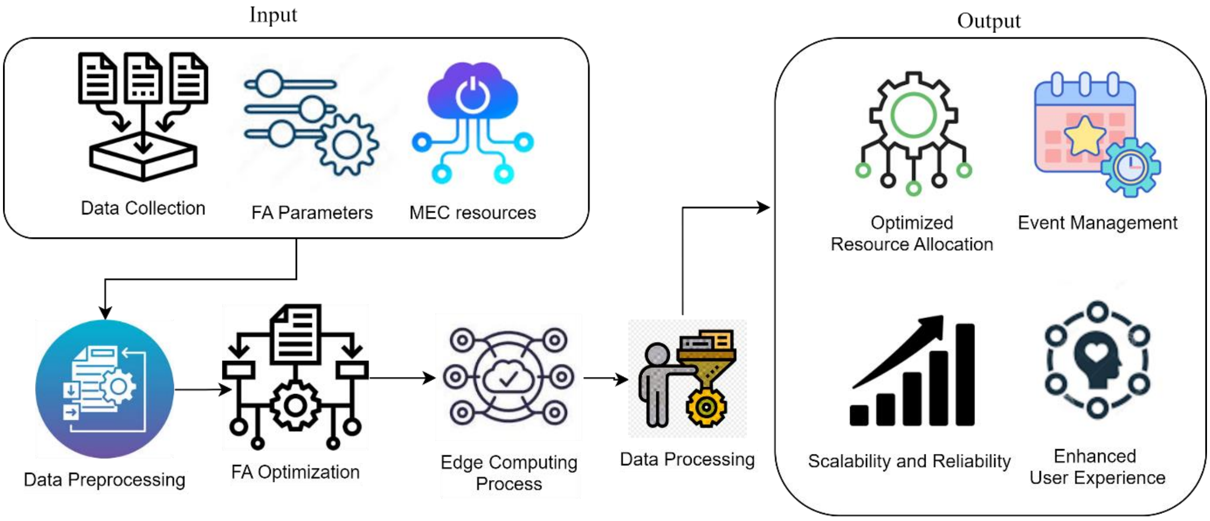

Fig 2. A high-level overview of the MEC-FOA Method.

Then it updates the positions of the fireflies, analyzes fitness functions, and finds out how to distribute resources optimally. Using MEC, computing activities may be transferred to edge nodes, guaranteeing processing with minimal latency and allowing for dynamic resource distribution throughout the network. The process consists of multiple steps, such as cleaning and normalizing input data through data preprocessing, initializing the model, and optimizing using FOA to attract and guide fireflies to ideal solutions. Efficient task processing at the edge nodes is guaranteed by MEC-managed assigning tasks and resource allocation, which undergo continual modifications in response to real-time sensor and user input data. This integrated system improves resource usage, schedules and manages sporting events better, and provides users with better personalised services and recommendations, which leads to better user experiences. Future planning and enhancements can be informed by the extensive data insight and reports provided, which offer useful information about the utilization of resources, event results, and user satisfaction. Because of its scalability and agility, the system can manage growing amounts of data and requests from users, respond instantly to changing conditions to keep people safe, make it more fun, and make the ice and snow sports sector run more efficiently.

The following sections discuss the proposed method's uses in the ice and snow sports industry.

i. Enhanced Design of Venues and Facilities

Venues for ice and snow activities can benefit from the FOA's consideration of accessibility, topography, energy efficiency, and safety when planning its layout and design. While optimizing, MEC's computational power and low-latency processing capabilities make real-time simulations and analyses possible. The goal function of FOA is to minimize energy consumption, maximize access, or improve the spectator experience, while the decision factors could include the location of lifts, paths, facilities, and infrastructure. Optimal venue design for improved productivity and user happiness can be achieved by combining FOA and MEC. This can be achieved by the eqn (1).

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$$Y^* = am_y\left(\omega_1 \times E(Y) - \omega_2 \times A(Y) + \omega_3 \times S(Y)\right) \quad (Eq. 1)$$

where Y is the decision variable that includes lifts, trails, facilities, and infrastructure, $E(Y)$ is the function for energy consumption, $A(Y)$ is the function for accessibility, $S(Y)$ is the function of the spectator experience. $\omega_1, \omega_2, \omega_3$ are the weights assigned to each objective to reflect their relative importance. $am_y()$ is the function for minimizing the argument. Y^* ends FOA optimization.

ii. Optimizing the Performance with Real-Time Video Analytics

MEC permits edge-based, real-time video processing to coach and monitor athletes' performance. By considering performance indicators and limitations, FOA can optimize video evaluation methods, training treatments, and coaching tactics. Athletes' performance, injury prevention, and training schedule optimization are the goal functions, and training intensities, technique tweaks, and coaching feedback tactics are the decision variables. This potent combination allows data-driven coaching decisions, individualized training programs, and real-time analysis for better athlete growth and performance.

iii. Enhancing the Virtual and Augmented Reality Experience

MEC can generate and process augmented reality and virtual reality content with low latency for ice and snow sports venues, creating immersive experiences. FOA can improve the development, rendering, and distribution of AR/VR content by considering network circumstances, device capacity, and user preferences. Content resolution, rendering methods, and delivery tactics are all examples of decision variables that could impact the objective function's ability to improve the user experience, reduce latency, or maximize resource utilization.

iv. Optimizing Connected Wearables and Equipment:

Connected devices and wearables worn by coaches and athletes can take advantage of MEC's minimal latency processing and evaluation of data capabilities. By considering metrics for performance and operational restrictions, FOA can optimize equipment design, sensor setups, and data processing algorithms. Equipment dimensions, sensor locations, and data processing methods are all examples of choice factors that could contribute to an objective function that seeks to optimize performance, reduce energy usage, or optimize data transmission.

The proposed MEC-FOA may create a robust optimization framework for the ice and snow sports business. This framework can consider operational and resource limitations, allowing for improved user experiences, real-time decision-making, and optimized performance.

Algorithm 1 Pseudocode for the proposed FOA
Define the optimization problem and objective function f(x) (e.g., minimize energy consumption, maximize performance metrics, optimize event schedules) Define decision variables x = (x1, x2, ..., xn) (e.g., equipment dimensions, venue layouts, training schedules, event timings) Define constraints (if any) (e.g., safety regulations, budget limitations, venue capacities)

```
Initialize the n fireflies population (potential solutions) x_i (i = 1, 2, ..., n)
Define light absorption coefficient γ
Define randomization parameter α
Define initial attractiveness β_0

while (termination criteria is not met)
   for i = 1 to n (n fireflies)
      for j = 1 to n (n fireflies, inner loop)
         if (f(x_j) < f(x_i))  // if brighter than i
            r_ij = distance(x_i, x_j)
            β = β_0 * exp(-γ * r_ij^2)  // attractiveness varies with distance
            rand = random number in [0, 1]
            x_i = x_i + β * (x_j - x_i) + α * (rand - 0.5)  // move i towards j
         end if
      end for j
      // Check and handle constraints for x_i
   end for i

   Rank the n fireflies and find the current best solution
   Evaluate the best solution with domain experts for feasibility and practicality
end while

Return the best solution
```

Optimizing ice and snow activities is the speciality of the offered approach, which integrates the FOA with MEC. Whether you're trying to optimize venue design, minimize energy consumption, or maximize athlete performance, it will outline an optimization issue. decision variables, and restrictions. Before deploying the MEC infrastructure—which consists of the edge nodes and an orchestrator—at the appropriate places, a first population of fireflies is created, representing viable solutions. The edge nodes, part of the main loop, receive all possible solutions and use their computational power and low-latency capabilities to process and assess them locally. To handle restrictions, the algorithm then moves Firefly towards brighter solutions by following the conventional FOA stages. Domain experts assess the best solution, and the process repeats until termination requirements are satisfied. This process culminates in the return of the optimal solution, which integrates FOA and MEC for optimal efficiency and practicality in the ice-snow sports sector.

4. Results and Discussions

The proposed MEC-FOA framework is anticipated that the ice-snow sports industry will experience notable enhancements in multiple domains. Higher efficiency, aerodynamics, weight distribution, and convenience are the end goals of this field's efforts to standardize the design of ice skates, skiing, snowboards, and safety gear. Topography, easy access, energy efficiency, and environmental effects are some of the issues expected to be more efficiently considered during venue planning and design. Optimizing the event's schedule and logistics is to make the most efficient use of the venue's capability, broadcast windows, and athletes' availability. By combining MEC's low latency processing capabilities with algorithms tuned for FOA, data-driven decision-making and personalized training programs can be enhanced through real-time feedback and performance evaluation. The plan to enhance user experiences includes optimal content distribution, real-time performance analysis, and low-latency augmented and virtual reality experiences. Optimizing linked wearables and equipment for improved functionality and energy efficiency is another goal of the integration. In section 3.1, the dataset that was used for this investigation is explained.

a. Experimental Setup

In this section, the suggested MEC-FOA is contrasted with more traditional approaches, such as the approach for path planning using Multiclass Neural Networks (MNN) [12], the method for movement classification using Convolutional Neural Networks (CNN-RTIPF) [14], and the method for consumer behaviour analysis using group identification algorithms (GIA) [16]. Out of all the methods discussed, the FOA-MEC optimisation framework uses edge computing's real-time processing capabilities and low latency to address additional industrial challenges. These problems include equipment design, venue planning, event time management, and enhancing user experiences. If implemented, combining optimisation methodologies with edge computing would improve snow and ice sports domain decision-making based on data, operational effectiveness, and resource allocation. To get this comparison, we might use these metrics.

Latency: Edge computing's ability to provide low-latency processing is a huge boon to the MEC-FOA approach. A latency metric, such as complete latency or response time, could be used to evaluate a performance improvement over typical cloud-based or centralized approaches. Eqn 2 helps to calculate the latency L.

$$L = P(t) + T(t) + Pg(t) \qquad (Eq.2)$$

where $P(t)$ is the Processing time by the system, $T(t)$ is the data transmission time from source to destination, and $Pg(t)$ is the signal's propagation time to travel from the source to the destination. It optimizes resource allocation, space design, event scheduling, and more by leveraging MEC's low-latency capacity for processing at the network's edge and using FOA. Fig 3 shows the low-latency advantages of MEC-FOA, comparing its end-to-end latency (the total of the process, transmission, and propagation periods) to that of traditional methods such as MNN, CNN-RTIPF, and GIA.

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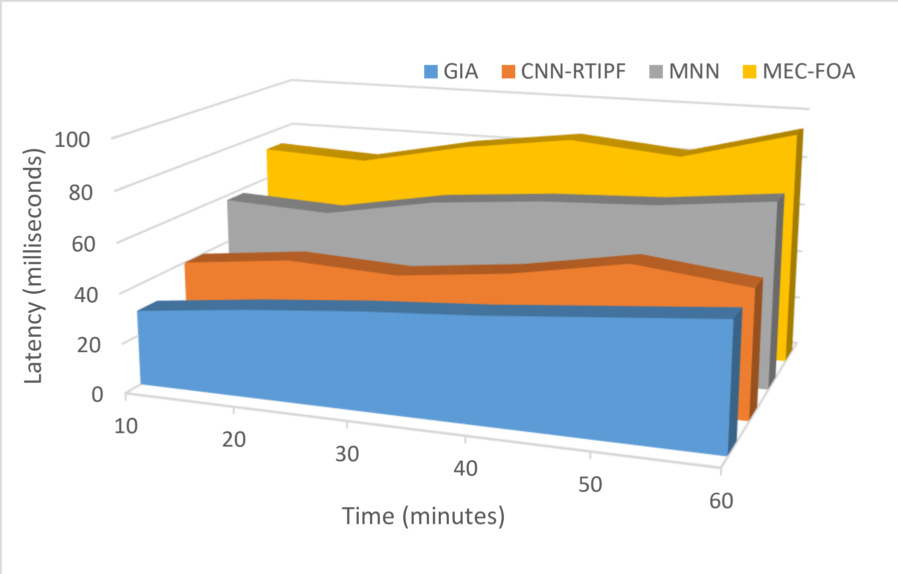

Fig 3. End-to-End Latency comparison

Displayed latency values for MEC-FOA show how combining FOA's optimization with MEC's edge computing can improve user experiences and operational efficiency for ice and snow sports applications by providing real-time data processing with reduced latency.

Resource Utilization: Resource usage rate, throughput, and resource wastage are some measures that can quantify resource consumption.

a. Resource Utilization Rate (RUR): The utilization rate is the percentage of available resources being used. It is determined by the eqn 3.

$$RUR = \frac{AR}{TR} \qquad (Eq.3)$$

where AR is the actual resource usage and TR is the total available resources.

b. Throughput (T): A system or process's throughput is its ability to finish tasks at a certain rate. The tasks accomplished by eqn 4 are.

$$T = \frac{TC}{TT} \qquad (Eq.4)$$

where TC is the number of tasks completed and TT is the time taken to complete a task.

c. Resource Wastage (RW): It can be calculated as the difference between the total number of available resources and the resources used. It is shown in the eqn 5.

$$RW = TR - AR \qquad (Eq.5)$$

where AR is the actual resource usage and TR is the total available resources.

These measures can show how well the MEC-FOA method optimizes resource allocation and usage compared to more traditional approaches. Fig 4 compares these metrics with the conventional methods to the proposed MEC-FOA method.

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Metric	GIA	CNN-RTIPF	MNN	MEC-FOA
Resource Utilization Rate (%)	52	65	78	95
Throughput (tasks/sec)	48	56	80	94
Resource Wastage (units)	56	42	21	96

Fig 4. Comparison of Resource Utilization

Fig 4 shows how the suggested MEC-FOA approach stacks up against more traditional algorithms in terms of resource utilization. These alternative methods include the Group Identification Algorithm (GIA), CNN-RTIPF, and Multiclass Neural Networks (MNN). The MEC-FOA framework is anticipated to outperform task-specific optimization approaches due to its integration of the FOA with MEC capabilities. Compared with the other algorithms, MEC-FOA achieves better resource utilization rates (95%) and throughput (94 tasks/sec) while losing only 4 units of resources. This shows how the optimization of FOA and the edge computing of MEC work together to improve resource consumption for ice and snow sports applications.

User Experience Metrics:

User experience metrics, such as ratings for satisfaction, immersion, or perceived quality, could be compared using real-time analytics, AR, and VR.

$$Average\ User\ Experience = \frac{\sum_{k=1}^{n} Metric_k}{n} \qquad (Eq.6)$$

The total number of user experience metrics that need to be evaluated is represented by n, and each individual measure, including the sense of quality, immersion, and satisfaction rating, is marked by $Metric_k$.

Metric	GIA	CNN-RTIPF	MNN	MEC-FOA
Perceived Quality	5	6.8	8.9	9.5
Immersion	4.6	5.4	7.6	9
Satisfaction Rating	5.3	5.9	7	9.8

Fig 5. Comparison of User Experience Metrics

Fig 5 shows that when compared to more traditional algorithms, the MEC-FOA framework provides a better user experience for ice and snow sports. These algorithms include CNN-RTIPF, Multiclass Neural Networks (MNN), and the Group Identification Algorithm (GIA). Evaluation criteria for the proposed MEC-FOA method can include satisfaction ratings, perceived value, and immersion, all of which are indicators of how effective real-time analytics, augmented reality, and virtual reality experiences are. Presenting low-latency AR/VR, improving content distribution, and providing real-time

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performance data are currently the primary goals of the MEC-FOA team in their pursuit of better user experiences.

Operational Efficiency:

The suggested MEC-FOA method has applications in maintenance scheduling, event organization, and venue management. One way to measure the operational efficiency of the MEC-FOA system is to look at more traditional measures like operational expenditures, downtime, or productivity. This can be calculated in eqn 10.

a. Operational cost: This statistic captures all operational expenses over a certain time frame, given in eqn 7.

$$Operational\ Cost = Fixed\ Cost + Variable\ Cost \qquad (Eq.7)$$

b. Downtime: This metric measures the sum of all the times operations are stopped because of maintenance or other problems. It is given in eqn 8.

$$Downtime = Total\ Scheduled\ Downtime + Total\ Unscheduled\ Downtime \qquad (Eq.8)$$

c. Productivity: The ratio of output to input is quantified by this metric. It is calculated in the eqn 9.

$$Productivity = \frac{Total\ Output}{Total\ Input} \qquad (Eq.9)$$

$$Operational\ Efficiency\ score = \frac{NOC + ND + NP}{3} \qquad (Eq.10)$$

where NOC is the normalized operational cost, that is the inverse of eqn 7. ND is the normalized downtime, that is inverse of eqn 8, and NP is the normalized productivity, that is the inverse of eqn 9.

Metric	GIA	CNN-RTIPF	MNN	MEC-FOA
NOC	0.000009	0.000014	0.00002	0.00003
ND	0.02	0.05	0.09	0.15
NP	90	100	130	180

Fig 6. Comparison of Operational Efficiency

Fig 6 compares the proposed MEC-FOA framework with traditional ice and snow sports industry algorithms. The MEC-FOA approach optimises event scheduling, logistics, and maintenance planning, to improve operational efficiency as measured by metrics like normalized operational cost, downtime, and productivity. The MEC-FOA framework can improve operational efficiency for various ice and snow sports facility management and operation applications, as shown by the superior values of the key operational efficiency metrics.

5. Conclusion

The ice and snow sports business is experiencing increasing demands and obstacles, and this study introduces a new framework called MEC-FOA that integrates the FOA with MEC. The suggested method uses FOA's strengths in real-time data optimization and dynamic resource allocation and MEC's skills in distributed processing and low latency. Quick data processing and evaluation, reduced latency, and an improved user experience are all results of MEC-FOA's use of computing resources deployed at the network's edge. Rest assured that FOA will efficiently allocate these edge computing resources, meeting the dynamic demands of the sector and optimizing important performance metrics. Immersive occasions, real-time performance information, and insights are what the MEC-FOA architecture is designed to provide to coaches, players, and spectators. Faster responses, lower computational overhead, and better real-time judgments are just a few ways the proposed solution enhances the user experience. By integrating algorithms for optimization with edge computing technologies, the MEC-FOA framework presents a possible answer to the issues faced by the ice and snow sports sector. Industry and customers benefit from the MEC-FOA framework's various applications, which include enhanced performance, better resource management, and quicker data processing. Accurate and comprehensive data from many sources, including IoT devices, consumer preferences, and historical records, is essential for the suggested architecture to function. The optimisation process's success depends on the data's precision and comprehensiveness. Just think about how much stronger and more useful the system may be by adding cutting-edge optimization techniques, like unconventional approaches or machine learning algorithms.

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