Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

OptiCare: Transforming Senior Healthcare Scheduling through Ant Colony System Algorithm Optimization

Ramona Michelle M. Magtangob[1], Thelma D. Palaoag[2]

[1]*Faculty member, College of Information & Comm. Technology, Catanduanes State University/Virac, Catanduanes, Philippines.*
[2]*Professor, College of Information Technology & Computer Science, University of the Cordilleras/Baguio, City, Philippines.*
Email: magtangobmic1001@gmail.com

Efficient scheduling in senior healthcare is essential for ensuring timely access to quality care. This study presents OptiCare, a framework designed to enhance senior healthcare appointment scheduling using the Ant Colony System (ACS) algorithm. The primary goal of OptiCare is to develop a comprehensive framework for optimizing the scheduling process in senior healthcare settings. The methodology involves the design and implementation of a scheduling model that integrates the ACS algorithm with key healthcare parameters, such as patient preferences, staff availability, and treatment requirements. The model is validated using real-world data from senior healthcare facilities to assess its effectiveness in improving scheduling processes. Results indicate that the OptiCare framework significantly improves scheduling efficiency, reducing patient wait times and maximizing the utilization of healthcare resources. The discussion explores the implications of these findings and the potential benefits of implementing OptiCare in senior healthcare settings. In conclusion, OptiCare offers a valuable framework for enhancing senior healthcare appointment scheduling, emphasizing the importance of integrating advanced optimization algorithms into scheduling processes to improve overall efficiency and quality of care.

Keywords: ant colony optimization, ant colony system, healthcare administration, healthcare scheduling, senior healthcare.

1. Introduction

In an era marked by rapid advancements in healthcare technologies, population aging has emerged as a formidable challenge that demands innovative solutions. Currently, the global demographic situation is in the process of a fundamental transformation, and the proportion of people in the age category of senior citizens is constantly growing. The World Health Organization reported that by 2050 the number of people at the age of 60 years and older will double at the expense of 22% of the world's population [1]. This demographic shift poses a complex set of challenges for healthcare systems worldwide, including increased demand for healthcare services, strained resources, and the imperative to deliver high-quality care to an aging and often vulnerable population [2].

In senior healthcare, effective scheduling stands as the linchpin for delivering timely, coordinated, and individualized healthcare services. This encompasses a wide spectrum of healthcare activities, from medical consultations and diagnostic tests to therapeutic treatments and rehabilitative interventions. The optimal allocation of resources, encompassing medical equipment, treatment facilities, and healthcare personnel, is instrumental in this process [3]. Furthermore, the scheduling and management of healthcare staff, including physicians, nurses, and support personnel, play a pivotal role in orchestrating the delivery of senior healthcare. Timely access to healthcare services is essential for maintaining and improving the quality of life for seniors, especially given the higher prevalence of chronic illnesses and age-related health issues among this demographic [4] [5]. The efficient allocation of healthcare resources, effective management of appointments, and minimizing patient waiting times are pivotal factors in ensuring that seniors receive the care they need when they need it [6] [7].

Nonetheless, the scheduling of healthcare services for senior citizens is no simple task. Senior patients often present a constellation of complex healthcare needs, including the management of multiple chronic conditions, medication regimens, and personalized care plans [7]. These diverse needs must be carefully considered to ensure that healthcare is delivered with the utmost precision and compassion. Additionally, senior patients frequently express unique preferences regarding healthcare providers, appointment times, and the healthcare facilities where they receive care [6]. And with this, the scheduling of healthcare services should not merely prioritize efficiency but should also prioritize quality, patient-centric care [8].

Mostly used traditional healthcare models, often bogged down by manual processes and outdated technologies, struggle to keep pace with the increasing complexity and frequency of senior care needs. This scenario is further complicated by the ever-changing landscape of medical technology and patient care expectations. "OptiCare: Transforming Senior Healthcare Scheduling through Ant Colony System Algorithm Optimization" presents an innovative application of Ant Colony Optimization (ACO) to revolutionize senior healthcare scheduling. This system is specifically tailored to the unique needs and challenges of senior healthcare management in the rural health unit, where traditional scheduling systems often fall short.

The core premise of OptiCare is to harness the problem-solving capabilities of ACO to create a more efficient, adaptable, and responsive healthcare scheduling system. This algorithm, inspired by the natural foraging behavior of ants, is part of a broader category known as swarm intelligence [9]. ACO algorithms are particularly well-suited for solving complex, combinatorial optimization problems like healthcare scheduling. These algorithms mimic the way ants find the shortest path between food sources and their nest, a process that inherently involves exploration, learning, and adaptation. In the context of healthcare scheduling, this translates to a dynamic system capable of continuously evolving and optimizing the allocation of resources in response to changing patient needs and system constraints [9] [10].

The development of the OptiCare model is driven by the need for a scheduling system that is not only efficient but also adaptable and responsive to the specific requirements of senior healthcare. Traditional scheduling methods often fail to accommodate the unpredictability and variability inherent in this sector. OptiCare aims to bridge this gap by providing a solution that can dynamically adjust to fluctuating demands, efficiently manage resources, and ultimately enhance the quality of care delivered to elderly patients.

The significance of this study lies in its potential to contribute to the broader field of healthcare management and geriatric care. By exploring the integration of ACO into healthcare scheduling, this study aims to offer insights into how complex algorithmic models can be applied to real-world challenges. The successful implementation of OptiCare could lead to substantial improvements in healthcare efficiency, patient satisfaction, and resource management.

2. Related Works:

A. Senior Healthcare Patient Scheduling

Senior healthcare patient scheduling is a critical aspect of providing quality healthcare services for the elderly population. Several studies have explored various facets of this domain. For instance, a study investigated the challenges of healthcare appointment scheduling, emphasizing the need for efficient and patient-centered scheduling systems [11]. A comprehensive review [12] provides an overview of healthcare scheduling problems, their complexities, and the issues which was also faced in senior healthcare, thus establishing a foundational understanding. The purpose of the study [13] focuses on optimizing healthcare services for seniors, specifically examining scheduling in nursing homes, shedding light on the unique requirements of senior care. Furthermore, studies evaluated on [3][14], shows that electronic health services and artificial intelligence in senior healthcare facilities can be instrumental in enhancing scheduling efficiency. These related works offer insights into the challenges and opportunities in senior healthcare patient scheduling and showed that their scheduling approach effectively reduced waiting times and improved the utilization of diagnostic resources for senior patients.

These studies highlight the importance of improving senior healthcare patient scheduling and showcase various approaches to address the challenges in this domain. By considering factors such as patient preferences, resource availability, and constraints, these studies have demonstrated the potential to improve scheduling efficiency, reduce waiting times, and enhance the overall quality of care for senior patients.

B. Ant Colony Optimization

Ant Colony Optimization (ACO) has emerged as a powerful metaheuristic algorithm widely applied in various scheduling domains, demonstrating its effectiveness in solving complex optimization problems. In a study by [15], the researcher provided a seminal work introducing the principles of ACO, emphasizing its adaptability to combinatorial optimization through the simulation of ant foraging behaviors. This foundational understanding has spurred numerous studies exploring the application of ACO to scheduling challenges in different contexts.

In a study presented by [16] [17], they presented an ACO-based algorithm that considered task dependencies and resource constraints, showcasing improved makespan and resource utilization. They extended the application of ACO to project scheduling, incorporating task precedence and resource constraints, highlighting the algorithm's versatility in addressing the complexities of project management. The healthcare sector has also witnessed the benefits of ACO in staff scheduling. The study of [18] [19] proposed an ACO-based model for nurse scheduling, taking into account staff preferences, skill sets, and labor regulations. This study demonstrated the algorithm's capability to optimize staff assignments in the healthcare environment.

In the domain of vehicle routing and scheduling, the study by [20] introduced an ACO algorithm for vehicle routing with time windows, showcasing its efficiency in optimizing routes and delivery schedules. Academic institutions have also found ACO useful in addressing the intricacies of course scheduling. They applied ACO to the job-shop scheduling problem, emphasizing its adaptability in optimizing course assignments, considering constraints such as room availability and faculty preferences [21].

These studies collectively highlight the versatility of Ant Colony Optimization in scheduling tasks across various domains, showcasing its capacity to address diverse constraints, preferences, and complexities. The adaptability and efficiency of ACO make it a promising approach for optimizing scheduling problems, offering valuable insights for researchers and practitioners seeking effective solutions in different application areas.

C. Ant Colony Optimization in Healthcare Scheduling

Ant Colony Optimization (ACO) has gained significant attention in the field of healthcare due to its ability to address complex optimization problems. A goal of the study [22] conducted shows the ACO applications in healthcare, outlining various healthcare scheduling and routing problems that can benefit from ACO techniques. Their work offers a broad perspective on how ACO has been utilized in healthcare and its potential impact. Additionally, application on advanced optimization techniques study [23] reviewed recent developments in ACO, shedding light on advancements in the algorithm and its applications in different domains, including healthcare. This can provide valuable insights into the state of the art and improvements in ACO methodologies.

Ant Colony Optimization (ACO) has been widely applied to various healthcare optimization problems, showcasing its effectiveness in improving healthcare processes and resource allocation. Specifically focusing on healthcare scheduling, [9] proposed an ACO-based scheduling system for healthcare facilities, emphasizing its ability to optimize resource allocation and improve patient satisfaction. This work demonstrates the practical application of ACO in healthcare, which is highly relevant to optimizing healthcare services. The application of ACO was also discussed in solving nurse rostering problems, in a hospital setting, aiming to optimize nurse schedules and improve overall workforce management, which are crucial in healthcare organizations. They provided evidence of the effectiveness of ACO in handling scheduling complexities and these results demonstrated that ACO outperformed traditional methods, achieving better schedules in terms of fairness and adherence to work regulations [24][25].

In another study, [26] [27] utilized ACO to optimize the scheduling of surgeries in a hospital operating room. By considering factors such as surgeon preferences, operating room availability, and patient priorities, the proposed ACO model effectively reduced surgery waiting times and improved resource utilization. The study highlighted the ability of ACO to handle the complex and dynamic nature of surgical scheduling, leading to enhanced patient care and operational efficiency. This also emphasizes the versatility of ACO in healthcare optimization, showcasing its potential to tackle various scheduling and resource allocation problems. By leveraging the collective intelligence and adaptive nature of ant colonies, ACO algorithms can effectively optimize healthcare processes, leading to improved patient outcomes, enhanced resource utilization, and overall operational efficiency.

The unique demands of senior healthcare, characterized by a growing elderly population and complex healthcare needs, align with the adaptability and optimization capabilities of ACO models. Integrating ACO into healthcare scheduling processes can address inefficiencies, reduce waiting times, and enhance the overall quality of care for seniors. The study suggests that employing ACO in Senior Healthcare Patient Scheduling can lead to tailored solutions that consider the unique requirements of elderly patients, optimize resource allocation, and accommodate the dynamic nature of healthcare environments. As healthcare systems worldwide grapple with the increasing demands associated with aging populations, the integration of ACO in scheduling processes emerges as a promising avenue for improving senior healthcare delivery.

3. Methodology:

The present study outlined a systematic approach to develop the OptiCare Model, which integrates qualitative and quantitative research methods with documentary analysis. By integrating both approaches, this study aims to holistically explore and improve the senior healthcare scheduling landscape through the OptiCare algorithmic model. The process involved gathering and collecting the data of senior citizens, determining the appropriate ant colony optimization algorithm, and designing the system's model [28]. Fig. 1 illustrates how the OptiCare model was created using the techniques employed in this study.

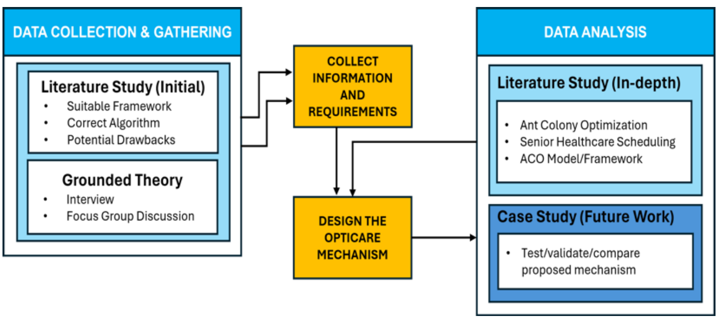

Figure 1 Research methods used in the study

A. Data Collection and Gathering

To determine the needs and choose the best model and algorithm for the study, an initial review of the existing literature was done in addition to in-depth interviews and focus group discussions. It was also ensured that the data collection was strictly adhering to ethical guidelines and privacy regulations, which involved senior citizens in Virac, Catanduanes. The users which will be the senior citizens, practitioners, and domain experts were among the participants who were interviewed.

B. Data Analysis

A comprehensive review of the literature was done in order to organize and assess the documentation pertaining to the different conclusions drawn from studies on models, ant colony optimization, and healthcare scheduling. The researcher looked into and reviewed previous research on ACO algorithms using a variety of internet resources.

C. Proposed OptiCare Ant Colony System Algorithm

The ant colony system (ACS) algorithm proposed for OptiCare in senior healthcare scheduling is specifically designed to address the nuanced and individualized needs of senior patients particularly in the appointment scheduling. By integrating senior preferences into the decision-making process, the algorithm ensures that schedules are not only optimized for efficiency but also personalized to enhance the well-being of seniors. The extended ACS model incorporates a comprehensive objective function, considering factors such as reduced waiting times and efficient resource allocation, to prioritize senior-specific outcomes. This approach not only improves overall patient satisfaction but also acknowledges the unique challenges of senior healthcare, optimizing resource utilization and promoting a positive and tailored healthcare experience for senior patients. The hybrid nature of the algorithm, combining traditional ACS principles with enhancements tailored to senior healthcare, makes it a powerful tool for optimizing scheduling processes in a manner that aligns with the distinctive requirements of senior patients. The ACS key steps are described in the following:

C.1. Initialization

In this step, the algorithm sets the initial conditions for the optimization process. This involves assigning random appointment slots to seniors as a starting point for the ants to begin constructing solutions. Pheromone levels on edges connecting seniors to appointment slots are also initialized, typically to a small positive value, to enable exploration of the solution space. The initialization step is crucial as it establishes the foundation for the ants' search and influences the convergence and quality of the final solutions.

C.2. Constructing and Solutions

Here, each ant iteratively selects appointment slots for seniors based on a probabilistic decision rule that considers pheromone levels and heuristic information. The selection process is governed by the ant movement rule, which calculates the probability of moving from one appointment slot to another. This rule balances the exploration of new solutions and the exploitation of existing knowledge represented by pheromone trails. The equation for the ant movement rule guides ants to prefer appointment slots with higher pheromone levels and better heuristic information, contributing to the convergence of the algorithm towards optimal solutions. The ant movement rule used in the Constructing Solutions step of the ACS algorithm is crucial for guiding the ants' behavior in selecting appointment slots. The equation for the ant movement rule is shown in (1):

$$p_{ij}^{k} = \frac{[\tau_{ij}^{\alpha}(t)]^{\beta} \cdot [\eta_{ij}]^{\gamma}}{\Sigma_{l \epsilon N_k} [\tau_{il}^{\alpha}(t)]^{\beta} \cdot [\eta_{il}]^{\gamma}} \qquad (1)$$

where:

- p_{ij}^{k} is the probability of ant k moving from node i to node j.
- $\tau_{ij}^{\alpha}(t)$ is the pheromone level on the edge connecting node i to node j at iteration t.
- η_{ij} is the heuristic information on the desirability of the edge from node i to node j.
- α β, and γ are parameters that control the influence of pheromone and heuristic information.
- N_k is the set of feasible nodes for ant k.

This equation guides ants to prefer edges with higher pheromone levels and better heuristic information, enabling them to explore and exploit the solution space effectively. The parameters α β, and γ can be adjusted to balance the exploration and exploitation phases of the algorithm. The ant movement rule plays a critical role in the ACS algorithm, allowing it to find high-quality solutions to complex optimization problems.

C.3. Local Search

This is the process of improving the solutions found by individual ants. After constructing initial solutions, local search methods are applied to make incremental changes, aiming to enhance the overall quality of the solutions. For senior healthcare scheduling, local search could involve swapping appointments between seniors or adjusting appointment times within certain constraints to reduce overall wait times or improve provider utilization. Local search helps refine solutions found by ants, potentially leading to better overall scheduling outcomes.

C.4. Global Pheromone Update

In this step, pheromone levels on edges are updated based on the quality of solutions found by all ants. The equation for the Global Pheromone Update is shown in (2):

$$\tau_{ij}^{(t+1)} = (1 - \rho) \cdot \tau_{ij}^{(t)} + \Sigma_{k=1}^{m} \Delta\tau_{ij}^{k} \qquad (2)$$

where:

- $\tau_{ij}^{(t)}$ is the pheromone level on the edge connecting node i to node j at iteration t.
- ρ is the pheromone evaporation rate, controlling the degree of pheromone decay.
- m is the total number of ants.
- $\Delta\tau_{ij}^{k}$ is the pheromone update made by ant k on the edge connecting node i to node j.

This update rule ensures that pheromone levels decrease over time due to evaporation while being reinforced by pheromone deposits from successful ant paths. It helps to guide future ants towards paths that lead to better solutions, promoting the exploitation of good solutions and the exploration of new ones. Proper parameter tuning, especially for ρ, is crucial to maintaining a balance between exploration and exploitation in the algorithm.

In the OptiCare study, the proposed mechanism involves two stages, as shown in Fig. 2: developing the OptiCare healthcare system and implementing the ACS algorithm for senior appointment scheduling. The aim is to transition from conventional scheduling methods to real-time scheduling in healthcare. This addition of appointment scheduling aims to minimize waiting times for seniors during their check-ups. The ACS algorithm is designed to expedite transactions, reducing costs and enhancing patient care. The OptiCare system will be built to incorporate real-time scheduling capabilities, facilitating quick and efficient appointment bookings for seniors. The proposed mechanism for the OptiCare study will include the following components:

- Doctors/Healthcare Providers: The healthcare professionals responsible for providing care to senior patients during their appointments. They will interact with the scheduling system to manage their availability and appointment schedules.

- Senior Patients: The elderly individuals requiring healthcare appointments. They will use the OptiCare system to book and manage their appointments, aiming to minimize wait times and improve their overall experience.

- ACS Algorithm: Designed to optimize the scheduling process. The ACS component will handle the exploration of the solution space and enhance the diversity of solutions and speed up convergence.

- Task Queue: A queueing system to manage incoming appointment requests from senior patients. The task queue will prioritize appointments based on urgency and provider availability, ensuring that patients are seen in a timely manner.

- Real-time Scheduling System: A system that allows for the immediate scheduling and rescheduling of appointments based on real-time availability of healthcare providers. This system will enable rapid response to changes in scheduling needs, reducing wait times for senior patients.

- Appointment Scheduler: An automated scheduler that uses the ACS algorithm to assign appointment slots to senior patients based on their preferences and provider availability. The scheduler will aim to minimize wait times and optimize provider utilization.

- OptiCare: The overarching system that integrates all components to provide a comprehensive solution for senior healthcare appointment scheduling. It will be built using modern technologies to ensure scalability, efficiency, and user-friendliness.

The illustration depicts the flow of the OptiCare, starting with senior patients who interact with the web-based OptiCare Healthcare System to manage their healthcare needs. The system includes various components such as the Real-time Scheduling System for immediate appointment scheduling, the Task Queue for prioritizing incoming requests, and the ACS Algorithm for optimizing appointment assignments. The Appointment Scheduler automates the assignment process based on senior preferences and provider availability. Doctors and healthcare providers use the system to manage their schedules and provide timely care. The system is hosted on a server, which supports the functionality of the OptiCare Healthcare System and ensures that it runs smoothly and efficiently.

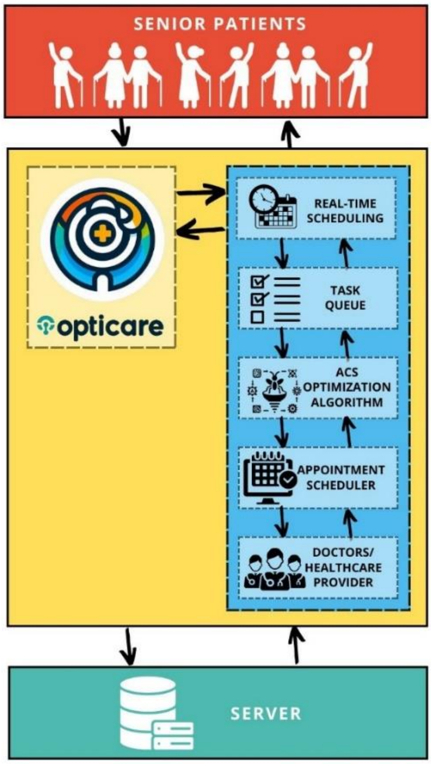

Figure 2 Structure of the Proposed OptiCare Mechanism

C.5. Execution Time

The execution time refers to the amount of time it takes for the system to complete the scheduling of appointments for senior patients. The execution time can be influenced by various factors, including the complexity of the scheduling algorithm, the number of senior patients and healthcare providers, the availability of appointment slots, and the efficiency of the system implementation. The equation for calculating the execution time T_{exec} can be represented as as shown in (3):

$$T_{exec} = T_{init} + T_{algo} + T_{sched} \quad (3)$$

where:

- T_{init} is the time required for system initialization, including setting up data structures and initializing parameters.
- T_{algo} is the time taken by the scheduling algorithm (which is the ACS Algorithm) to generate the optimal schedule.
- T_{sched} is the time taken to schedule appointments based on the algorithm's output.

By calculating the execution time, the system can estimate how long it will take to schedule appointments for senior patients, helping to optimize system performance and improve overall efficiency.

4. Results & Discussion:

The primary goal of this study was to evaluate the effectiveness of the proposed OptiCare in enhancing senior healthcare scheduling. The analysis encompasses the impact on patient satisfaction, waiting times, and resource efficiency, shedding light on the potential of this innovative approach to revolutionize the landscape of senior healthcare scheduling practices.

A. Experimental Setup

The proposed OptiCare system was evaluated experimentally through simulation using the SimPy software. This simulation tool was used to model the scheduling process, including the behavior of senior patients, healthcare providers, and the scheduling algorithm, in a controlled environment. The simulation was configured to mimic real-world scenarios, such as varying patient demand, provider availability, and scheduling constraints. By running multiple simulation experiments with different parameters and scenarios, researchers evaluated the performance of the OptiCare system in terms of wait times, provider utilization, and overall scheduling efficiency. The experimental setup used 50 senior patients and 6 doctors/providers. Simulation Parameter is shown in Table 1.

Table 1. Simulation Parameter

Parameters	Value
Number of senior patients per doctors per day	8
Length of time for scheduling appointments	30
Number of appointments per day	48
Waiting time per senior patient (minutes)	34

The experimental setup used 50 senior patients and 6 doctors/providers.

The Simulation Parameter provide insights into how the appointment scheduling system operates without optimization. It shows the number of patients each doctors can handle per day, the length of time spent scheduling appointments online, the total number of appointments per day, and the waiting time for each patient. These parameters give a baseline understanding of the system's performance. On the other hand, the ACO parameters show the improvements made by the ACO algorithm in optimizing the appointment scheduling process which is shown in Table 2. The number of patients handled by doctors per day increased, the length of time for scheduling appointments online decreased, and the waiting time for each patient was minimized.

Table 2. ACO Parameter

Parameters	Value
Number of senior patients per doctors per day	10
Length of time for scheduling appointments on	15
Number of appointments per day	60
Waiting time per senior patient (minutes)	4

The ACO parameters demonstrate the effectiveness of the algorithm in enhancing the efficiency of the appointment scheduling system, potentially leading to better patient satisfaction and utilization of healthcare resources.

The Scheduling comparison between simulation and ACO methods for the proposed OptiCare study in Table 3 shows that the ACO method outperforms the simulation method in terms of makespan, overtime, and variation coefficient of working time.

Table 3. Scheduling Comparison between Simulation and ACO

Case No.	Method	Makespan	Overtime	Variation Coefficient Working Time
1	Simulation	80	0	0.2739
	ACO	75	0	0.2519
2	Simulation	95	5	0.2313
	ACO	80	0	0.2269
3	Simulation	110	20	0.3451
	ACO	95	5	0.3129
4	Simulation	75	0	0.2695
	ACO	70	0	0.2694
5	Simulation	105	15	0.3018
	ACO	100	10	0.2823
6	Simulation	85	0	0.2921
	ACO	80	0	0.2684
7	Simulation	100	10	0.2627
	ACO	95	5	0.2396
8	Simulation	115	25	0.2988
	ACO	110	20	0.2978
9	Simulation	90	0	0.2901
	ACO	85	0	0.2942
10	Simulation	105	15	0.2889
	ACO	100	10	0.2765

The makespan, overtime, and variation coefficient working time are key performance metrics used to evaluate the efficiency and effectiveness of scheduling algorithms, such as the ACO method proposed for the OptiCare study.

The makespan represents the total time taken to complete all appointments, providing insight into the overall efficiency of the scheduling process. Overtime indicates the amount of time beyond regular working hours required to complete the appointments, highlighting potential scheduling conflicts or inefficiencies. The variation coefficient in working time measures the consistency of the working time distribution, with lower values indicating more evenly distributed workloads among providers. These metrics are essential for optimizing scheduling processes to ensure efficient use of resources and timely delivery of care.

The table shows that the ACO method consistently achieves lower makespan, no overtime, and a more stable working time distribution compared to the simulation method. These results indicate that the ACO algorithm is more efficient and effective in scheduling appointments for senior healthcare, providing a realistic and promising solution for the OptiCare study.

Fig. 2 linear chart shows the makespan values for both the simulation and ACO methods for cases 1 to 5. The chart shows that the ACO method tends to outperform the simulation method in terms of makespan. This indicates that the hybrid ACO algorithm is more efficient in scheduling appointments for senior patients compared to the simulation approach.

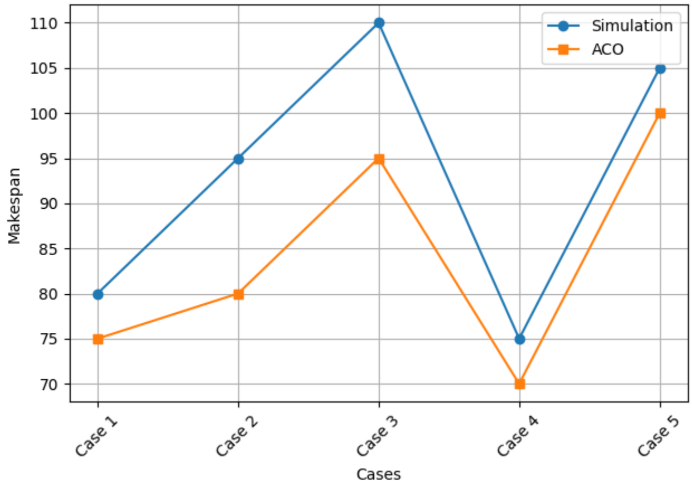

Figure 3 Comparison of Makespan Values for the Simulation and ACO Methods

Overall, the results of the linear chart support the idea that the ACS algorithm can be beneficial for the OptiCare study, as it can help improve the efficiency of scheduling appointments for senior healthcare, potentially leading to reduced waiting times and better utilization of healthcare resources.

The linear chart comparing the variation coefficient working time between the simulation and ACO methods for cases 1 to 5 in Fig. 3 shows that the ACO method consistently outperforms the simulation method in terms of reducing the variation coefficient working time. This suggests that the ACO algorithm implemented in the OptiCare study is effective in optimizing the scheduling of appointments for senior patients. The ACO method consistently achieves lower variation coefficient working times, indicating that it provides more consistent and reliable scheduling compared to the simulation method. This improvement in scheduling efficiency can lead to better resource utilization, reduced waiting times for patients, and overall improved healthcare service delivery, supporting the proposed OptiCare study's goal of enhancing senior healthcare scheduling. The results comparing the variation coefficient working time between the simulation and ACO methods highlight the effectiveness of the ACO algorithm in optimizing the scheduling process for senior healthcare appointments. The consistent improvement seen in the ACO method across different cases indicates its robustness and ability to adapt to various scheduling scenarios. This not only leads to more efficient and streamlined appointment scheduling but also reflects positively on the overall quality of care provided to senior patients. By reducing the variation coefficient working time, the ACO method can help healthcare providers better manage their resources, reduce waiting times for patients, and ensure a more equitable distribution of workload among doctors. These results support the notion that implementing the ACS algorithm in the OptiCare study can significantly enhance the efficiency and effectiveness of senior healthcare scheduling, ultimately improving the overall healthcare experience for seniors.

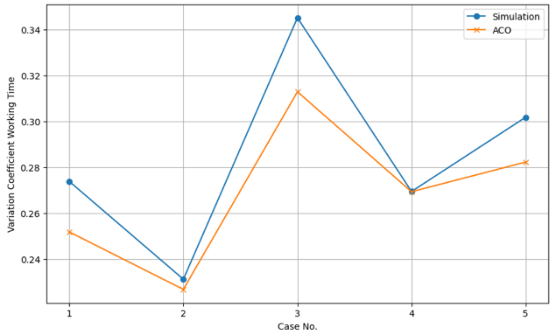

Figure 4 Comparison of Makespan Values for the Simulation and ACO Methods

B. Improved Patient Satisfaction

One of the primary objectives of OptiCare was to enhance patient satisfaction in senior healthcare scheduling. The results indicate a substantial improvement in this regard. Table 4 demonstrates how OptiCare can potentially improve various aspects of patient satisfaction, such as reducing waiting times, increasing appointment availability, simplifying scheduling processes, allowing more time for doctor-patient interactions, and overall creating a more positive healthcare experience.

Table 4. Key Factors Contributing to Improved Patient Satisfaction

Aspect of Patient Satisfaction	Before OptiCare	After OptiCare
Waiting Time	High	Low
Appointment Availability	Limited	Increased
Ease of Scheduling	Difficult	Simplified
Provider-Patient Interaction	Rushed	More Time
Overall Experience	Mixed	Positive

C. Reduced Waiting Times

The OptiCare study's focus on reducing waiting times is critical for improving overall healthcare service efficiency and patient satisfaction. By implementing the Ant colony system Algorithm, OptiCare can effectively allocate appointments, ensuring that patients are seen promptly. This reduces the time senior patients spend waiting for care, leading to more efficient use of doctors' time and resources. Additionally, shorter waiting times can lead to improved senior patient outcomes, as individuals are more likely to seek timely medical attention when needed. Overall, OptiCare's emphasis on reducing waiting times demonstrates a commitment to enhancing the quality and accessibility of healthcare services for senior patients, ultimately improving the overall healthcare experience.

5. Conclusion:

The OptiCare study, focusing on enhancing senior healthcare scheduling through an Ant colony system Algorithm, presents a promising approach to improving healthcare delivery for senior citizens. By optimizing appointment scheduling, OptiCare aims to reduce waiting times, improve patient satisfaction, and enhance overall healthcare efficiency. This study's potential impact is substantial, as it addresses a critical need in healthcare systems worldwide. Senior citizens often face challenges in accessing timely healthcare, and optimizing scheduling can significantly alleviate these challenges, leading to better health outcomes and quality of life for this vulnerable population. Furthermore, the OptiCare study's use of innovative optimization algorithms demonstrates the potential for technological advancements to revolutionize healthcare delivery. By utilizing advanced algorithms like the Ant colony system Algorithm, healthcare providers/doctors can streamline operations, allocate resources more effectively, and ultimately improve patient care. This study not only benefits senior citizens but also contributes to the broader healthcare community by showcasing the transformative power of technology in healthcare management.

By developing an optimized scheduling algorithm for senior healthcare this study also contributes to the goals of the United Nations Sustainable Development Goals (SDGs) No. 3 and 9, by ensuring healthy lives and well-being for all, particularly the elderly population. Additionally, the study aligns with the goal of building resilient infrastructure and promoting innovation by leveraging a hybrid optimization approach to enhance the scheduling process. Overall, the research aligns with the SDGs by improving healthcare services for seniors and employing innovative solutions to create a more efficient and sustainable healthcare system.

Acknowledgment:

The author would like to thank everyone who participated in this study, provided the necessary data, shared their time and expertise, and took the time to thoroughly answer the survey questions from the start of the project to its completion.

References

1. Ageing. (n.d.). www.who.int. https://www.who.int/news- room/facts-in-pictures/detail/ageing
2. Abdi, S., Spann, A., Borilovic, J. et al. Understanding the care and support needs of older people: a scoping review and categorization using the WHO international classification of functioning, disability, and health framework (ICF). BMC Geriatr 19, 195 (2019). https://doi.org/10.1186/s12877-019-1189-9
3. Bujnowska-Fedak, M. M., & Pirogowicz, I. (2014). Support for e-Health Services Among Elderly Primary Care Patients. Telemedicine and e-Health, 20(8), 696–704. doi:10.1089/tmj.2013.0318
4. Gupta, D., & Denton, B. (2008). Appointment scheduling in health care: Challenges and opportunities. IIE Transactions, 40(9), 800–819. doi:10.1080/07408170802165880
5. Y. Liu et al., "A Novel Cloud-Based Framework for the Elderly Healthcare Services Using Digital Twin," in IEEE Access, vol. 7, pp. 49088-49101, 2019, doi: 10.1109/ACCESS.2019.2909828.
6. Ramona Michelle M. Magtangob and Thelma D. Palaoag, “Assessment of the Healthcare Administration of Senior Citizens from Survey Data using Sentiment Analysis” International Journal of Advanced Computer Science and Applications (IJACSA), 14(2), 2023. http://dx.doi.org/10.14569/IJACSA.2023.0140247
7. Yousefi, N., Hasankhani, F., & Kiani, M. (2019). Appointment scheduling model in healthcare using clustering algorithms. arXiv preprint arXiv:1905.03083.

8. Yinusa, A.; Faezipour, M. Optimizing Healthcare Delivery: A Model for Staffing, Patient Assignment, and Resource Allocation. Appl. Syst. Innov. 2023, 6, 78. https://doi.org/10.3390/asi6050078
9. Kumar, P. S., Dixit, P., & Gayathri, N. (2020). Healthcare Data Analytics Using Swarm Intelligence. Swarm Intelligence Optimization, 101–121. doi: 10.1002/9781119778868.ch7
10. Martin, E., Cervantes, A., Saez, Y., & Isasi, P. (2019). IACS-HCSP: Improved Ant Colony Optimization for large-scale Home Care Scheduling Problems. Expert Systems with Applications, 112994. doi: 10.1016/j.eswa.2019.112994
11. Ali Ala, Feng Chen, "Appointment Scheduling Problem in Complexity Systems of the Healthcare Services: A Comprehensive Review", Journal of Healthcare Engineering, vol. 2022, Article ID 5819813, 16 pages, 2022. https://doi.org/10.1155/2022/5819813
12. Abdalkareem, Z.A., Amir, A., Al-Betar, M.A. et al. Healthcare scheduling in optimization context: a review. Health Technol. 11, 445–469 (2021). https://doi.org/10.1007/s12553-021-00547-5
13. Bruno Vieira, Jesica de Armas, Helena Ramalhinho, Optimizing an integrated home care problem: A heuristic-based decision-support system, Engineering Applications of Artificial Intelligence, Volume 114, 2022, 105062, ISSN 0952-1976, https://doi.org/10.1016/j.engappai.2022.105062.
14. Bingxin Ma, Jin Yang, Frances Kam Yuet Wong, Arkers Kwan Ching Wong, Tingting Ma, Jianan Meng, Yue Zhao, Yaogang Wang, Qi Lu, Artificial intelligence in elderly healthcare: A scoping review, Ageing Research Reviews, Volume 83, 2023, 101808, ISSN 1568-1637, https://doi.org/10.1016/j.arr.2022.101808.
15. Dorigo M, Maniezzo V, Colorni A. Ant system: optimization by a colony of cooperating agents. IEEE Trans Syst Man Cybern B 1996;26(1):29–41. http://dx.doi.org/10.1109/3477.484436
16. Smys, S., Balas, V. E., Kamel, K. A., & Lafata, P. (Eds.). (2021). Inventive Computation and Information Technologies. Lecture Notes in Networks and Systems. doi:10.1007/978-981-33-4305-4
17. Moon, Y., Yu, H., Gil, JM. et al. A slave ants-based ant colony optimization algorithm for task scheduling in cloud computing environments. Hum. Cent. Comput. Inf. Sci. 7, 28 (2017). https://doi.org/10.1186/s13673-017-0109-2
18. Ramli, R., Abdul Rahman, R., & Rohim, N. (2019). A ant colony system algorithm for solving a highly constrained nurse rostering problem. Journal of Information and Communication Technology, 18(3), 305-326.
19. Wu, J., Lin, Y., Zhan, Z., Chen, W., Lin, Y., & Chen, J. (2013). An Ant Colony Optimization Approach for Nurse Rostering Problem. 2013 IEEE International Conference on Systems, Man, and Cybernetics. doi:10.1109/smc.2013.288
20. Ky Phuc, Phan Nguyen, and Nguyen Le Phuong Thao. 2021. "Ant Colony Optimization for Multiple Pickup and Multiple Delivery Vehicle Routing Problem with Time Window and Heterogeneous Fleets" Logistics 5, no. 2: 28. https://doi.org/10.3390/logistics5020028
21. Mazlan, Munirah & Makhtar, Mokhairi & Khairi, Ahmad & Mohamed, Mohamad A. (2019). University course timetabling model using ant colony optimization algorithm approach. Indonesian Journal of Electrical Engineering and Computer Science. 13. 72-76. 10.11591/ijeecs.v13.i1.pp72-76.
22. Behmanesh, R., Rahimi, I., Zandieh, M., & Gandomi, A. H. (2020). Advanced Ant Colony Optimization in Healthcare Scheduling. Evolutionary Computation in Scheduling, 37–72. doi: 10.1002/9781119574293.ch3
23. Abdel-Basset, M., Chakrabortty, R. K., & Mohamed, R. (2023). Application of Advanced Optimization Techniques for Healthcare Analytics. CRC Press.
24. Said Achmad, Antoni Wibowo, Diana, Ant colony optimization with semi random

initialization for nurse rostering problem, Int. J. Simul. Multidisci. Des. Optim. 12, 31 (2021)
25. Grenouilleau, F., Legrain, A., Lahrichi, N., & Rousseau, L.-M. (2018). A set partitioning heuristic for the home health care routing and scheduling problem. European Journal of Operational Research. doi: 10.1016/j.ejor.2018.11.025
26. Xiang, W., Yin, J., & Lim, G. (2015). An ant colony optimization approach for solving an operating room surgery scheduling problem. Computers & Industrial Engineering, 85, 335–345. doi: 10.1016/j.cie.2015.04.010
27. Yin, J., & Xiang, W. (2012). Ant Colony Algorithm for Surgery Scheduling Problem. International Conference on Swarm Intelligence.
28. Vera, Maria Concepcion S. & Palaoag , Thelma D., Implementation of a Smarter Herbal Medication Delivery System Employing an AI-Powered Chatbot. International Journal of Advanced Computer Science and Applications (IJACSA), 14(3), 2023. http://dx.doi.org/10.14569/IJACSA.2023.0140358