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DEHR: HYBRID OF TSOS IN DIALYSIS HEALTHCARE

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Abstract: Dialysis is a crucial lifeline for individuals battling renal disease and it is experiencing a growing demand. However, healthcare providers face significant challenges in managing the complexities and risks associated with this vital medical procedure. The current healthcare management systems often struggle to meet the unique demands of nephrology care. Traditional paper-based methods create barriers to accessibility, comprehensive record-keeping, and contribute to an increased risk of errors in patient treatment. In response to these challenges, the proposed Dialysis Electronic Health Record (DEHR) system aims to revolutionize nephrology care. By shifting away from traditional paper-based approaches to a digital platform, the DEHR system seeks to ensure comprehensive, accessible, and secure patient records. This project incorporates the Tabu Search Algorithm for Scheduling Optimization. This innovative algorithm improves the scheduling process, optimizing resource allocation, and minimizing wait times for patients undergoing dialysis. Embracing a user-focused and iterative development approach involving healthcare professionals, IT specialists, and patients, the DEHR system is crafted for adaptability. It integrates well-established software technologies and robust database systems to offer a holistic solution to the challenges faced in renal care. The DEHR system holds the promise of transforming renal care by enhancing provider efficiency, reducing errors, and empowering patients through improved self-management. The inclusion of a barcode scanning system streamlines check-in processes, contributing to a secure and user-friendly experience. This project, dedicated to improving data accuracy, providing timely reminders, and ensuring top-notch security, is poised to advance healthcare outcomes and elevate patient satisfaction within renal care settings.

Keywords: Dialysis, Electronic Health Record (EHR), Tabu Search Algorithm, Optimization Scheduling, TSOS Hybrid

1. INTRODUCTION

The landscape of nephrology healthcare, particularly in hemodialysis, is rapidly evolving due to the increasing number of patients requiring kidney care. Addressing the complexity and risks associated with kidney failure demands efficient record-keeping and improved treatment management. In response, the Dialysis Electronic Health Record (DEHR) system emerges as a transformative solution, replacing paper records with a modern digital platform. By ensuring accurate data management and integrating real-time reminders and smart barcode scanning, DEHR enhances patient experience and streamlines healthcare operations. Leveraging advanced algorithms like the Tabu Search Algorithm for Scheduling Optimization, the system optimizes clinic resources while prioritizing patient needs and treatment adherence. Developed through collaboration among healthcare experts, IT specialists, and patients, DEHR is flexible and interoperable, representing a significant advancement in renal care management. Ultimately, DEHR aims to enhance healthcare delivery for kidney patients by improving information accuracy, timeliness of reminders, and overall security, empowering both healthcare providers and patients in the management of kidney-related conditions.

2. RELATED WORKS

Addressing the multifaceted challenges faced by dialysis patients requires innovative technological solutions, as explored in various related works. Dialysis, essential for individuals with end-stage renal disease (ESRD), involves removing waste, salt, and excess water from the body, tasks normally performed by healthy kidneys. Significant challenges, including emotional and physical strains, dietary restrictions, and limited mobility during treatment, highlight the need for improvements in patient outcomes [1]. The integration of electronic health records (EHR) is a critical tool for enhancing care coordination and improving treatment quality and safety. Studies show that EHR implementation improves documentation time, guideline adherence, and reduces medication errors, although it has no impact on mortality [2]. Additionally, computerized patient records enhance patient care, decision-making, administrative tasks, and quality efforts [3]. Effective appointment management systems further optimize operations by improving patient appointment management, increasing staff productivity, and facilitating secure data storage and retrieval [4]. The scheduling process in haemodialysis services incorporates a multifaceted approach to optimize treatment delivery, considering treatment cycles, device utilization, and patient preferences [5]. The Dialysis Electronic Health Record (DEHR) system exemplifies an innovative solution, transitioning from paper records to a digital platform, enhancing accuracy, security, and convenience through features like smart barcode scanning for streamlined check-in and appointment management. These related works collectively underscore the importance of technological integration in improving dialysis care and patient outcomes.

2.1 Tabu Search

Tabu Search (TS), proposed by Fred Glover in 1986, is a powerful metaheuristic algorithm used to solve optimization problems by exploring solution spaces and avoiding local optima through historical knowledge and memory structures [6]. It uses a "tabu list" to prevent revisiting recent solutions, ensuring a comprehensive search [7]. The algorithm employs short- and long-term memory to guide the search, and aspiration criteria allow tabu moves if they yield better solutions [8].

The Tabu Search Algorithm serves as a powerful optimization method, particularly effective in navigating complex solution spaces to find optimal or near-optimal solutions while circumventing issues like cycling and local optima. It operates by iteratively exploring neighbouring solutions, intelligently selecting moves based on defined criteria, and leveraging memory structures to guide the search process effectively. The algorithm dynamically manages a tabu list to prevent revisiting past solutions excessively, balancing intensification and diversification strategies to refine the search trajectory. Hereafter, in figure 1 is a detailed pseudocode and figure 2 is a flowchart of the Tabu Search Algorithm are presented to elucidate its operational intricacies [8].

Tabu Search Algorithm

1. **begin TS**
2. TS_list = [];
3. S = initial solution;
4. S* = S;
5. **Repeat Step 2 to step 4**
6. Find the best admissible solution S1 belongs to Neighborhood of S
7. **if** f(S1) > f(S*) **then** S*:= S1;
8. S:= S1;
9. Update TS list TS_list;
10. **Until** the process, stopping criterion;
11. **End;**

Figure 1: Pseudocode of Tabu Search

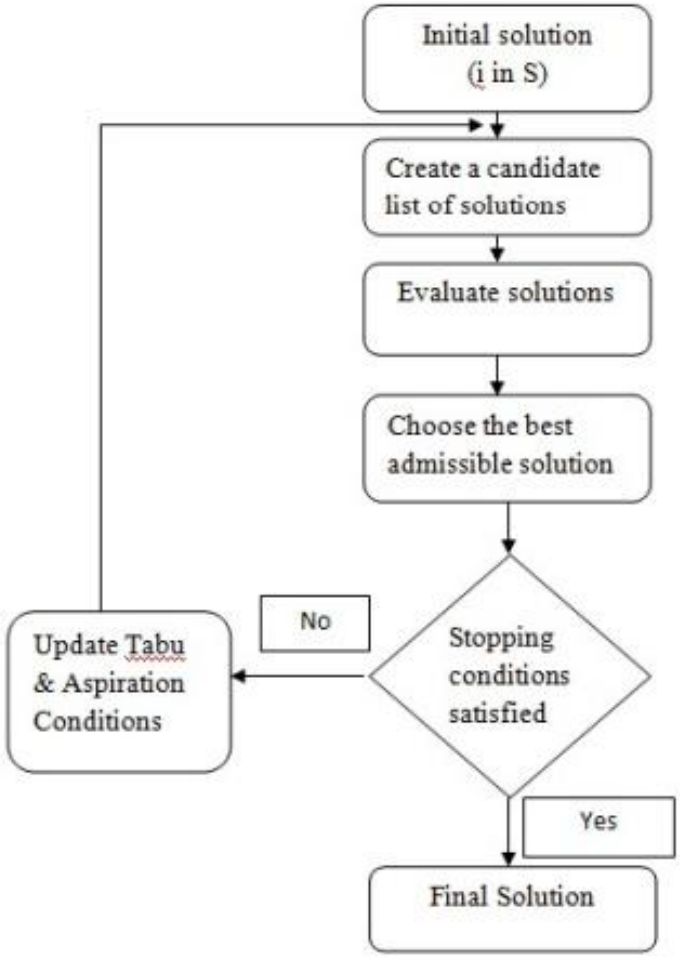

Figure 2: Flowchart of Tabu Search

In healthcare, TS optimizes appointment scheduling by efficiently allocating resources like medical staff and equipment, enhancing operations and patient satisfaction [9]. Research demonstrates its effectiveness in reducing patient waiting times and improving resource utilization through integrated mixed-integer programming, TS algorithms, and simulation models [9]. Another study presents a hybrid TS method for hospital bed allocation, balancing costs, and patient needs, which is also applicable to scheduling dialysis treatments [10]. This hybrid method combines local search with memory features and a token-ring approach, navigating solution spaces efficiently while avoiding local optima [10]. Solutions are presented as matrices showing bed assignments over time, considering patient preferences and medical needs [10].

Thus, TS is an effective metaheuristic algorithm that optimizes healthcare scheduling by exploring solution spaces efficiently and avoiding local optima. Its integration with mathematical models and simulations has shown substantial reductions in waiting times and improved service provider performance, underscoring the importance of advanced scheduling solutions for enhancing healthcare efficiency and patient satisfaction. Continued exploration of TS algorithms in healthcare promises further advancements in resource optimization and care delivery.

2.2 Optimization Scheduling

Optimization scheduling in healthcare entails crafting an efficient appointment system that minimizes patient waiting time, doctor idle time, and overtime, while maximizing patient satisfaction and resource utilization [11]. Scheduling optimization in healthcare is a multidimensional effort aiming at improving patient access, resource usage, and operational efficiency across a variety of healthcare settings. Efficient appointment scheduling is a vital feature. This includes scheduling patient appointments in accordance with the availability of healthcare personnel, examination rooms, and essential equipment. By matching patient demand to resource availability, healthcare institutions may reduce wait times, increase patient happiness, and assure timely access to care. Furthermore, advanced scheduling algorithms and software systems are increasingly being used to automate the process, taking into consideration aspects like as appointment times, provider availability, and patient preferences.

The significance of optimizing scheduling in dialysis healthcare is underscored by several key factors highlighted on the [12]. First, it enables the implementation of personalized treatment programs suited to each patient's specific medical circumstances, potentially increasing treatment efficacy and patient satisfaction [12]. Second, efficient scheduling not only aids in the proper management of medical resources, but it also reduces the load on both healthcare systems and patients by shortening wait times and optimizing resource allocation [12]. Third, ensuring treatment adequacy through correct scheduling is critical for patient health and well-being and using advanced optimization approaches like genetic algorithms allows healthcare professionals to manage difficult scheduling circumstances with greater accuracy and flexibility, resulting in improved patient outcomes and more efficient use of healthcare resources overall [12].

The implementation of various appointment scheduling policies in a hospital's ultrasound department is discussed in [13] with simulation optimization used to identify optimal solutions. Its highlights the trade-off between patients' waiting time and resources' idle time, considering factors such as patient inter-arrival times and available time slots [13]. Challenges include managing variability in patient arrivals and treatment durations while balancing workload among healthcare providers [13]. The outcomes provide valuable insights for hospital administrators to select the most suitable approach, aiming to balance patient wait times and resource allocation effectively [13].

Optimization scheduling is crucial in healthcare management, impacting patient satisfaction and service efficiency, with effective policies enhancing service quality within healthcare facilities. Adopting efficient scheduling strategies that are suited to the specific needs of dialysis patients and providers can increase service quality, simplify operations, and improve overall patient outcomes. Finally, optimized scheduling in dialysis care is critical in healthcare management, helping to provide high-quality and efficient patient-centered care in dialysis settings.

2.3 Dialysis Healthcare

Dialysis treatment is critical in treating kidney failure because it removes excess fluid and waste from the blood when the kidneys lack the ability to do so properly. Dialysis, which began in the 1940s and became a common treatment in the 1970s has become an integral part of modern medicine [14]. Millions of patients worldwide have benefited from its life-saving abilities. Today's dialysis centres provide complete care beyond the technical components of therapy, such as dietary support and psychological counselling. Ensuring equal access to dialysis services is a significant goal, emphasizing the need of providing important healthcare support to a wide range of communities.

Dialysis stands as a pivotal treatment for removing waste products and excess fluid from the bloodstream and playing a crucial role in managing kidney disease and failure. Although highly effective, it's crucial to acknowledge that dialysis does not completely replace all kidney functions and is not a cure for kidney-related conditions [14]. The selection between peritoneal dialysis (PD) and haemodialysis (HD), both treatments for end-stage renal disease (ESRD) hinges on individual medical conditions, patient preferences, and a thorough modality selection process [15]. PD leverages the patient's peritoneum for fluid and contaminant exchange from the blood, while HD employs a machine and dialyzer for blood cleansing [14]. This selection involves determining patient eligibility, presenting the modalities available, and engaging patients in the decision-making process to ensure the choice of the most suitable dialysis modality [15].

Collaboration between patients and healthcare providers is vital in determining the most appropriate dialysis type and setting, where seeking advice from others undergoing dialysis can offer valuable insights into treatment experiences. To enhance dialysis treatment effectiveness, adherence to prescribed treatment schedules is essential for optimal results, alongside following a personalized eating plan recommended by a kidney dietitian, engaging in regular physical activity, and maintaining open communication with the dialysis provider and pharmacist about medications, supplements, or herbal products [15]. These measures aim to maximize the benefits of dialysis therapy, contributing to an improved quality of life for those facing kidney-related challenges.

2.4 Hybrid of Scheduling Optimization Scheduling and Tabu Search In DEHR

Hybridizing tabu search with other optimization techniques provides several benefits, including improved exploration and exploitation capabilities, higher convergence rates, and greater adaptability to complex problems by combining tabu search's efficient search space exploration with the exploitation prowess of methods such as genetic algorithms or simulated annealing [16]. This integration not only balances the search for optimal solutions, resulting in a more robust and versatile framework capable of dealing with a wide range of optimization landscapes, but it also speeds up convergence by combining tabu search's ability to escape local optima with the rapid convergence of other algorithms [16].

The Dialysis Electronic Health Record (DEHR) system is designed to enhance patient record accuracy by transitioning from paper to digital methods. This shift ensures patient information is complete, accessible, and secure, reducing errors associated with handwritten records. Healthcare providers gain precise, up-to-date details on patient health, treatments, and progress, facilitating better decision-making and personalized care. Additionally, DEHR streamlines appointment scheduling, improving organization and efficiency, which benefits both providers and patients by reducing delays and wait times.

The DEHR system employs advanced algorithms, such as the Tabu Search Algorithm for Scheduling Optimization, to manage clinic resources effectively. This algorithm balances patient needs with clinic obligations, resolving scheduling conflicts by suggesting optimal alternative times. For example, if a conflict arises with a 9 AM slot, the system might suggest alternative times like May 29th at 9 AM or June 1st at 10 AM. The Tabu Search Algorithm uses memory structures to avoid revisiting recent solutions and employs strategies to explore new areas, ensuring efficient conflict resolution and optimal scheduling. Various optimization techniques, including Linear Programming (LP), Constraint Programming (CP), and Genetic Algorithms (GA), are integrated with the Tabu Search Algorithm to enhance scheduling efficiency. LP allocates resources like dialysis machines and staff, CP handles complex scheduling constraints, and GA iteratively improves scheduling solutions. Simulation techniques validate proposed schedules, ensuring they can handle real-world scenarios. This hybrid approach reduces waiting times, minimizes delays, and optimizes resource utilization, ultimately improving patient care.

Overall, the DEHR system represents a significant advancement in renal healthcare management. By leveraging cutting-edge technology, it offers more efficient, personalized, and secure healthcare management for kidney patients. The system helps doctors work more effectively, reduces errors, and encourages patient self-care, making healthcare more comprehensive, user-friendly, and safe for everyone involved.

3. DEHR FRAMEWORK

Integrating User-Centered Design (UCD) that shows in figure 3 into the Dialysis Electronic Health Record (DEHR) project is crucial for making sure the system meets the specific needs of healthcare professionals and patients in nephrology care. The challenges of managing haemodialysis patients, as mentioned in the summary, require a new solution, and UCD helps by involving end-users in the design process. This means talking to nephrologists, nurses, IT experts, and patients to make sure the DEHR system is customized for the demands of renal care. Using an iterative approach, where the design is improved based on real feedback, aligns with the project's goal of creating a user-friendly digital platform. Usability testing in the UCD framework ensures that the DEHR system is not just technologically advanced but also easy to use in the changing healthcare environment. In the end, UCD helps in creating a DEHR system that is safe, easy to access, and centered around the needs of patients in renal care facilities.

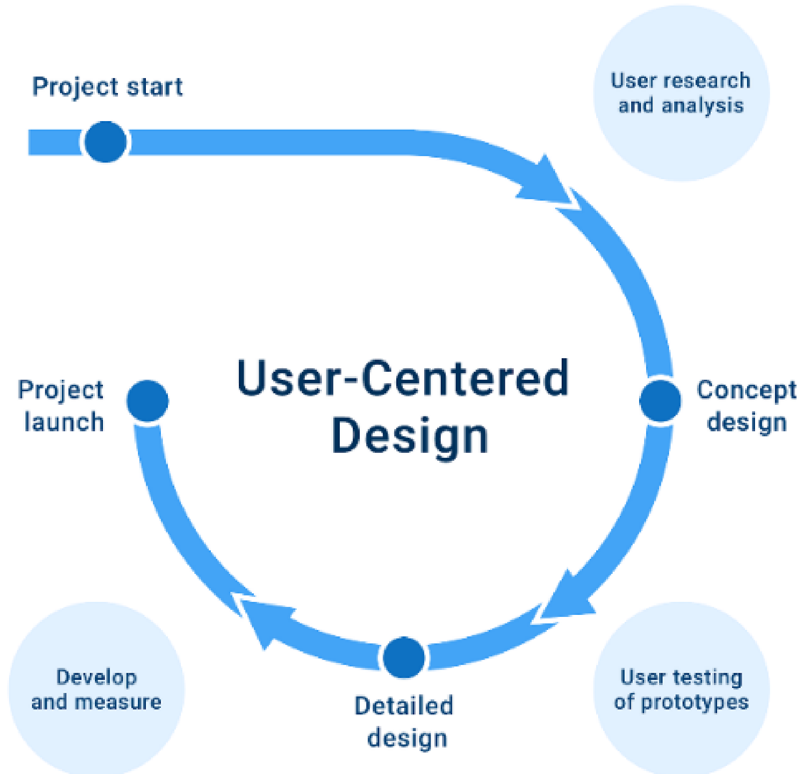

Figure 3: User Centered Design

The framework of the proposed Dialysis Electronic Health Record has been illustrated in figure 4. It is designed to streamline clinical operations through role-specific functionalities connected to a central database. Doctors, staff, patients, and administrators interact with the system through tailored interfaces that allow them to perform tasks such as managing patient records, diagnosing conditions, scheduling appointments, and handling medication regimens. Each role has its own set of permissions and capabilities, ensuring that sensitive medical information is accessed and modified appropriately. For instance, doctors can add treatment notes and prescribe medications, while patients can view their treatment schedules and receive notifications to ensure compliance.

At the heart of the system lies a robust database that securely stores all the data generated and utilized by the different user roles. This ensures data integrity and real-time availability of patient information, facilitating informed decision-making and efficient management of hospital resources. The system's design emphasizes the importance of a coordinated effort in healthcare delivery, where accurate and up-to-date patient information is readily accessible to authorized users, ultimately aiming to enhance the quality of patient care and optimize clinical workflows.

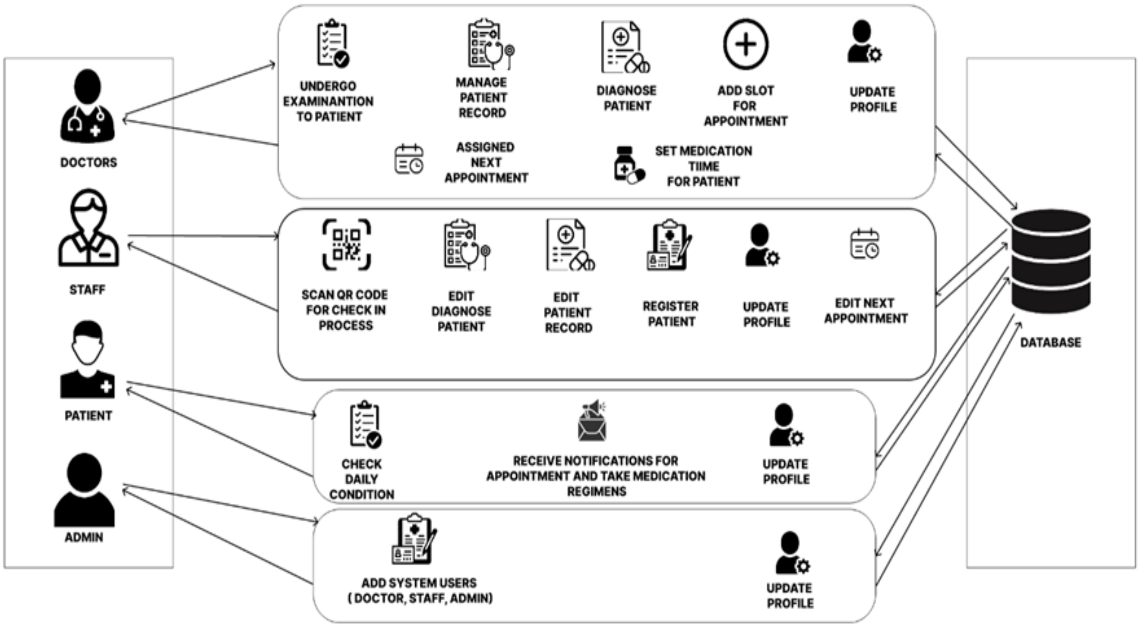

Figure 4: Framework of DEHR

4. RESULT AND DISCUSSION

In this section, we delve into the outcomes following the development and implementation of the Dialysis Electronic Health Record (DEHR), which has revolutionized nephrology healthcare, particularly in haemodialysis. Through rigorous testing and evaluation, DEHR has enhanced the efficiency and accuracy of patient information management by transitioning from paper-based to digital records. Integration of real-time reminders and a smart barcode scanning system has streamlined processes, improving patient adherence to treatment regimens. The utilization of advanced algorithms, like the Tabu Search Algorithm for Scheduling Optimization, ensures optimal resource allocation, enhancing clinic workflows. Collaborative development involving healthcare experts, IT specialists, and patients has tailored DEHR to meet unique nephrology care needs, resulting in a flexible and adaptive solution. Overall, DEHR's focus on information accuracy, timely reminders, and enhanced security empowers healthcare providers and improves healthcare delivery for kidney patients.

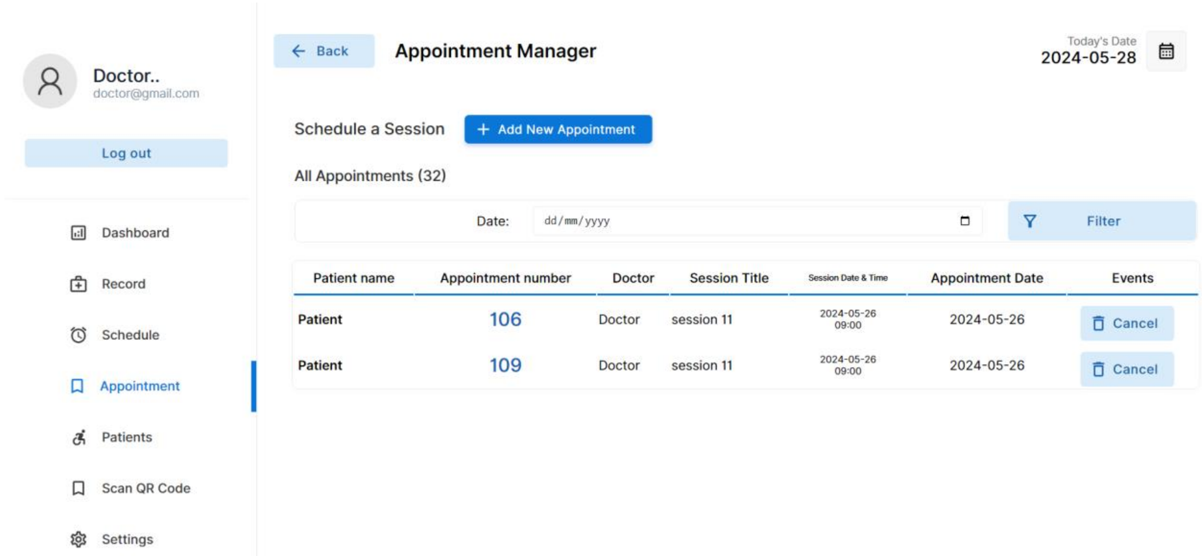

Figure 5: List of Appointment in DEHR

Figure 5 provides a detailed overview of appointments listed within the Dialysis Electronic Health Record (DEHR) system, highlighting its robust capability in organizing and managing patient schedules effectively. Each appointment entry is meticulously documented, encompassing essential details such as name appointment number, doctor name, session tittle, session date and time and appointment date. Through the DEHR interface, healthcare providers can seamlessly access and navigate this comprehensive appointment list, facilitating efficient scheduling and coordination of patient care. Additionally, the figure underscores DEHR's role in enhancing patient experience by ensuring timely ultimately contributing to improved treatment adherence and overall healthcare outcomes.

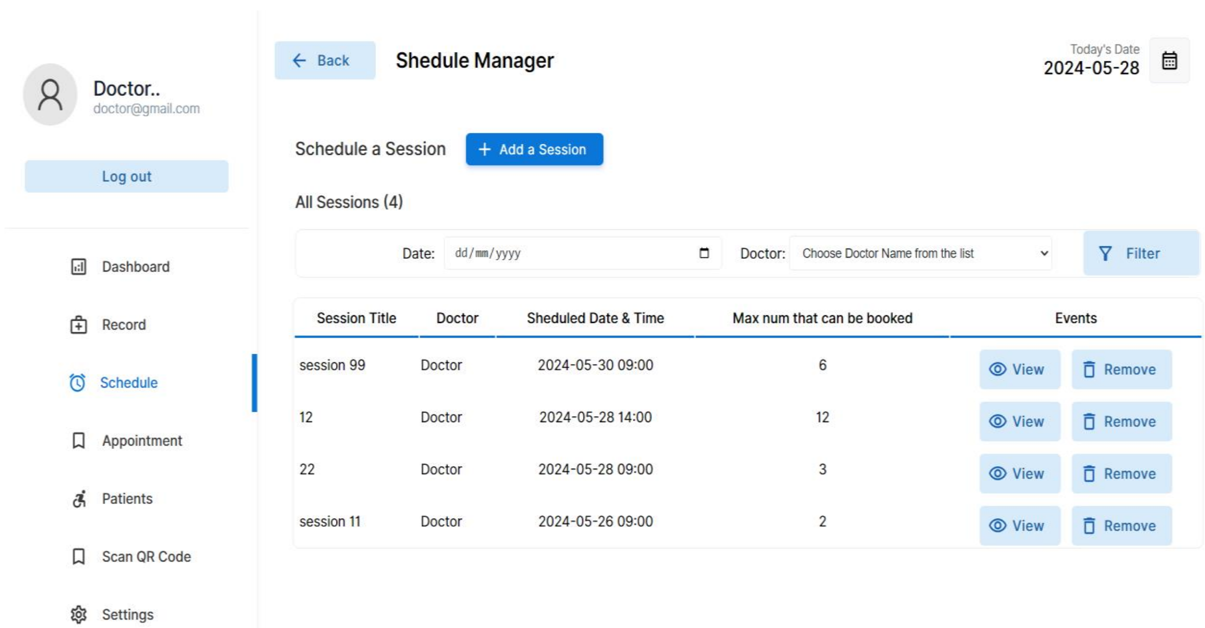

Figure 6: List of Session in DEHR

The subsequent figure 6 portrays a detailed compilation of sessions within the Dialysis Electronic Health Record (DEHR) system, delineating the availability of free time slots for healthcare providers. These sessions, derived from the doctor's schedule, signify periods during which medical professionals are available to accommodate patient appointments or other clinical responsibilities. It is noteworthy that the input of session timings by doctors may occasionally lead to conflicts, necessitating the utilization of the intended algorithmic approach, such as the Tabu Search Algorithm for Scheduling Optimization, embedded within DEHR. These conflicts may arise due to overlapping appointments or logistical constraints, underscoring the significance of algorithmic optimization in harmonizing clinic resources and maximizing patient care efficiency. By leveraging DEHR's algorithmic capabilities, healthcare providers can effectively resolve scheduling conflicts, ensuring optimal utilization of available session slots while prioritizing patient needs and treatment adherence.

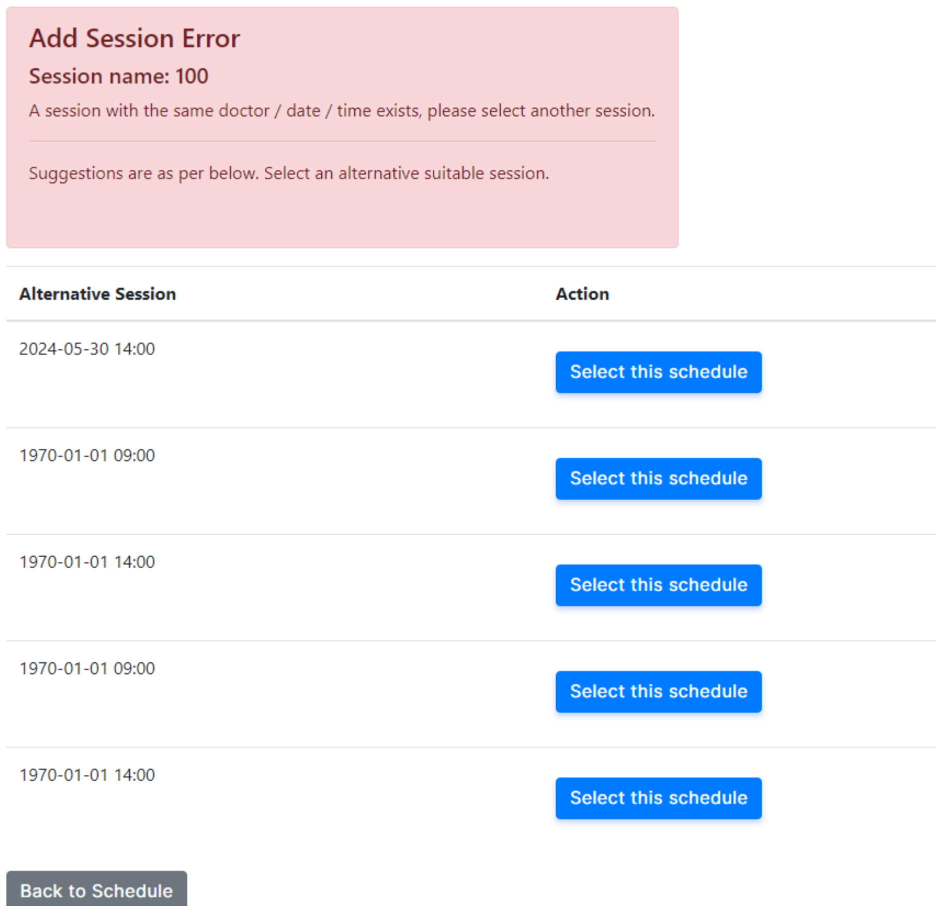

Figure 7: Add Session Error

Figure 7 illustrates the conflict resolution process facilitated by the Tabu Search Algorithm within the Dialysis Electronic Health Record (DEHR) system. When scheduling conflicts arise, such as overlapping time slots entered by doctors, the system employs the algorithm to analyse and resolve these conflicts. The figure showcases how the DEHR system identifies overlapping appointments and utilizes the Tabu Search Algorithm to suggest alternative times, ensuring optimal scheduling. By automatically proposing new time slots, the system enhances efficiency and minimizes disruptions, allowing healthcare providers to maintain a well-organized schedule and deliver timely patient care.

5. CONCLUSION

In conclusion, the Dialysis Electronic Health Record (DEHR) system represents a significant leap forward in renal healthcare management. By seamlessly integrating advanced algorithms such as the Tabu Search Algorithm for Scheduling Optimization, the DEHR system optimizes resource allocation and appointment scheduling, ultimately enhancing the quality of care for kidney patients. Through its collaborative approach involving healthcare experts, IT specialists, and patients, the DEHR system ensures that it meets the unique needs of nephrology care while promoting efficiency, accuracy, and security in healthcare operations. With its focus on improving patient outcomes, reducing errors, and facilitating better communication between healthcare providers and patients, the DEHR system emerges as a comprehensive solution designed to revolutionize kidney healthcare management. Its adaptability, user-friendliness, and commitment to leveraging technology underscore its pivotal role in reshaping the landscape of renal healthcare delivery, promising a brighter and more efficient future for individuals with kidney problems.

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References

[1] Himmelfarb, J., Vanholder, R., Mehrotra, R., & Tonelli, M. (2020). The current and future landscape of dialysis. *Nature Reviews Nephrology*, *16*(10), 573-585.

[2] Campanella, P., Lovato, E., Marone, C., Fallacara, L., Mancuso, A., Ricciardi, W., & Specchia, M. L. (2016). The impact of electronic health records on healthcare quality: a systematic review and meta-analysis. *The European Journal of Public Health*, *26*(1), 60-64.

[3] Lorch, J. A., & Pollak, V. E. (2004). Computerized patient record in dialysis practice. In *Replacement of Renal Function by Dialysis* (pp. 539-553). Dordrecht: Springer Netherlands.

[4] Marjudi, S. (2021). Patient Appointment Application for Mawar Medical Centre Unit–Dialysis. *Applied Information Technology And Computer Science*, *2*(2), 1720-1731.

[5] Liu, Z., Lu, J., Liu, Z., Liao, G., Zhang, H. H., & Dong, J. (2019). Patient scheduling in hemodialysis service. *Journal of Combinatorial Optimization*, *37*, 337-362.

[6] Gendreau, M., & Potvin, J. Y. (2005). Tabu search. *Search methodologies: introductory tutorials in optimization and decision support techniques*, 165-186.

[7] Díaz, E., Tuya, J., Blanco, R., & Dolado, J. J. (2008). A tabu search algorithm for structural software testing. *Computers & Operations Research*, *35*(10), 3052-3072.

[8] Prajapati, V. K., Jain, M., & Chouhan, L. (2020, February). Tabu search algorithm (TSA): A comprehensive survey. In *2020 3rd International Conference on Emerging Technologies in Computer Engineering: Machine Learning and Internet of Things (ICETCE)* (pp. 1-8). IEEE.

[9] Ala, A., & Chen, F. (2020, April). An appointment scheduling optimization method in healthcare with simulation approach. In *2020 IEEE 7th international conference on industrial engineering and applications (ICIEA)* (pp. 833-837). IEEE.

[10] Demeester, P., Souffriau, W., De Causmaecker, P., & Berghe, G. V. (2010). A hybrid tabu search algorithm for automatically assigning patients to beds. *Artificial Intelligence in Medicine*, *48*(1), 61-70.

[11] Lee, C. K. M., Ng, K. K. H., & Cheng, M. C. (2018, January). Appointment scheduling optimization for specialist outpatient services. In *Proceedings of the 2nd European conference on industrial engineering and operations management (IEOM)* (pp. 876-883).

[12] Choi, J. W., Lee, H., Lee, J. C., Lee, S., Kim, Y. S., Yoon, H. J., & Kim, H. C. (2017). Application of genetic algorithm for hemodialysis schedule optimization. *Computer Methods and Programs in biomedicine*, *145*, 35-43.

[13] Chen, P. S., Robielos, R. A. C., Palaña, P. K. V. C., Valencia, P. L. L., & Chen, G. Y. H. (2015). Scheduling patients' appointments: Allocation of healthcare service using simulation optimization. *Journal of healthcare engineering*, *6*(2), 259-280.

[14] *What is Dialysis?* (2024, January 29). National Kidney Foundation. https://www.kidney.org/atoz/content/dialysisinfo

[15] Blake, P. G., Quinn, R. R., & Oliver, M. J. (2013). Peritoneal dialysis and the process of modality selection. *Peritoneal Dialysis International*, *33*(3), 233-241.

[16] Mashinchi, M. H., Orgun, M. A., & Pedrycz, W. (2011). Hybrid optimization with improved tabu search. *Applied Soft Computing*, *11*(2), 1993-2006.