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Hybrid Model of Genetic Algorithms and Tabu Search Memory for Nurse Scheduling Systems

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ABSTRACT

The main challenge of the nurse scheduling problem (NSP)is designing a nurse schedule that satisfies nurses preferences at minimal cost of violating the soft constraints. This makes the NSP an NP-hard problem with no perfect solution yet. In this study, two meta-heuristics procedures—genetic algorithm (GA) and tabu search (TS) memory—were applied for the development of an automatic hospital nurse scheduling system (GATS_NSS). The data collected from the nursing services unit of a Federal Medical Centre (FMC) in Nigeria with 151 nursing staffs was preprocessed and adopted for training the GATS_NSS. The system was implemented in Java for selection, evaluation, and genetic operators (crossover and mutation) of GA alongside the memory properties of TS. Nurse shift and ward allocation were optimized based on defined constraints of the case study hospital, and the results obtained showed that GAT_NSS returned an average accuracy of 94%, 99% allocation rate, 0% duplication, 0.5% clash, and an average improvement in the computing time of 94% over the manual approach.

KEYWORDS

Genetic Algorithm (GA), Heuristics, Nurse Scheduling, Optimization, Tabu Search (TS) Memory

1 INTRODUCTION

Scheduling is the course of action of substances (individuals, undertakings, vehicles, addresses, tests, gatherings, and so forth) into an example in space-time so that requirements are fulfilled and certain objectives are accomplished (Rivera & Mesa, 2015). Developing schedules is not an easy task because several factors must be considered, some of which are time, space and other (frequently restricted) resources. The limitations are connections among the resources or between the elements and the patterns that limit the construction of the schedule. Most scheduling tasks are described as NP-hard problem due to the enormous administrative reuirements and optimizations.Shift Scheduling

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Problem (SSP) is considered as an advanced N-P hard problem (Özder, Özcan&Eren, 2019) and Nurse Scheduling Problem (NSP) fall in this category. ShiftScheduling (NS) has found application in different sectors such as examination scheduling (Abayomi-Alli *et al.*, 2019a); (Abayomi-Alli *et al.*, 2019b); Transportation (Guo*et al.*, 2017), flight scheduling (Chen *et al.*, 2019), machine scheduling (Nedaei, 2018;Wu *et al.*, 2018), social event scheduling (Bikakis, Kalogeraki&Gunopulos, 2019), occupation shop planning (Piroozfard, Wong&Hassan, 2016), e.t.c.

The service sector like the health care industry is presently experiencing massive expansion while still contributing positively to the Gross Domestic Product (GDP) of several countries(Ishola and Olusoji, 2020).The sector is highly service oriented and constitutes an important part of the service sector(Sisodia, 2019)but it involves varaious parties such as physicians, administrators, nurses, lab scientist, etc. to collaborate in order to provide care to patients(Barhoun*et al.*, 2019).Nurse's satisfaction with their schedules or roster helps in motivating them to provide quality care to patientsespecially when nursing services is the most important predictor of the patient's overall satisfaction with the hospital care (Olowe and Odeyemi, 2019;Gishu*et al.*, 2019).

Causmaecker&Berghe (2011) defined NSP as the appointment of several nurses to several shifts in such a way that hospital rules are not violated. In NSP, the objective is to appoint shifts to the nurses while satisfying the hospital's rules during the planning period. Hospitals and medical clinics' human resource, represent an extensive piece of the clinic's annual budgets. Hospital policy makers are therefore tasked with the responsibility of maximizing the available nurses and other health workers effectively. The issue is worsened by the inadequate number of nurses in most hospitals and medical centre especially in developing countries where the shortage of healthcare workers is more prevalent(Miseda*et al.*, 2017)and poor working environments in the work place will lead to unmotivated employees (Galli, 2020).

NSP is a subset of Staff or Shift Scheduling Problems (SSP) which appoints nurses to shifts and also wards each day while taking hard constraints (rules of hospitals) and soft constraints (preferences of nurses) into consideration. Designing the schedule is done such that the preferences of nurses are satisfied while reducing the cost of violating the soft constraints (Baskaran, 2016). NS can be defined as the act of appointing nurses to carry out set of tasks at certain wards in a hospital at a particular period. One obstacles associated with nurse scheduling is the constant lack of enough resources to satisfy the needs of the hospital. NS is usually done manually at the risk of not fulfilling some nursing rules set by the hospital or accommodating some staff's preferences.

Constraints are criteria or rules that must be followed or satisfied in order to develop the hospital nurse schedule or roster successfully. There two types of constraints, namely hard constraints and soft constraints. Hard constraints are the type of constraints that must be satisfied, they are compulsory and unavoidable. Hard constraints normally incorporate compulsory requirements from the nurse's contracts and other ground rules in hospital workflow. Soft constraints are typically those included with time prerequisites or close to personal calendars of the nurses. Soft constraints may not be satisfied, but it is desirable not to violate them so as to have a good and user centred schedule.

This study is motivated to develop a scheduling system that deals with the allocation of nurses to different shifts while satisfying the hard and soft constraints (Kim *et al.*, 2014). This issue is daring for any algorithm as:

1. Nurses with higher ranks can substitute those with lower ranks, but the reverse is not the case, thereby making it difficult to schedule different grades separately.
2. NS has a special day-night format where majority of the nurses are made to work either days or nights in a week but not both.

Nonetheless, because of working agreements, number of days worked is usually not equal to the number of nights, also number of hours worked during the night shift is greater than the number