DYNEX

NURSE SCHEDULING

Use case on the Dynex n.quantum computing platform

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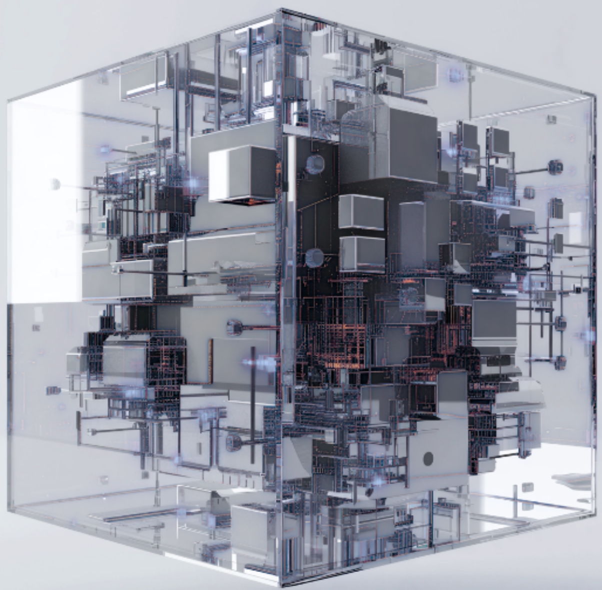
DYNEX N.QUANTUM COMPUTER

Taking advantage of a biological approach, neuromorphic computing emulates the parallel processing capabilities of the human brain.



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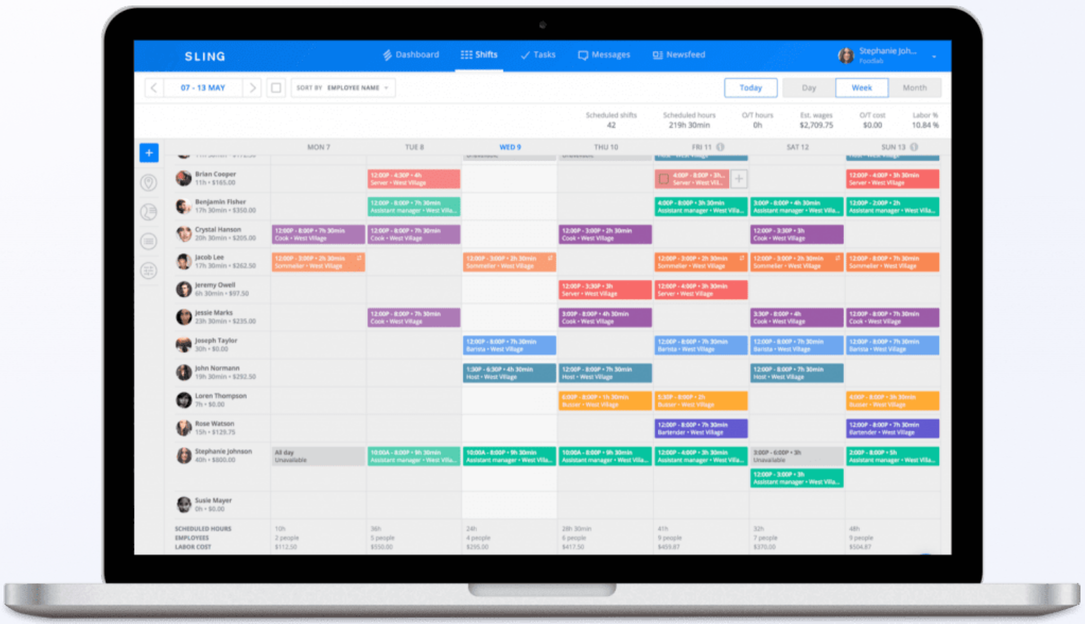
NURSE SCHEDULING PROBLEM

The "nurse scheduling problem" (NSP) is a type of optimization problem that focuses on creating effective work schedules for nurses. This problem is complex due to the need to balance various factors and constraints.

The NSP can be formulated as a mathematical optimization problem and solved on a quantum computing system.

QUANTUM OPTIMISATION TASK



The goal of solving the nurse scheduling problem is to produce a **feasible and efficient schedule** that meets all necessary constraints while optimizing for one or more objectives, such as **minimizing costs**, **maximizing nurse satisfaction**, or **ensuring high-quality patient care**.

NSP - OBJECTIVES

- **Shift Coverage:**
  Ensuring that all shifts are covered by the required number of nurses. This includes accounting for different shift types (day, night, weekend).
- **Nurse Preferences**:
  Incorporating the personal preferences and requests of nurses for specific days off or preferred shifts.
- **Legal and Contractual Constraints**:
  Adhering to labor laws and regulations, such as maximum working hours, minimum rest periods between shifts, and contractual obligations like vacation time and days off.
- **Skill Mix**:
  Ensuring that shifts have a balanced mix of nurses with different skill levels and specializations to provide high-quality patient care.
- **Fairness**:
  Distributing shifts equitably among nurses to prevent burnout and maintain job satisfaction. This includes rotating weekend and night shifts fairly among all nurses.
- **Continuity of Care**:
  Trying to schedule the same nurses for the same patients or units over multiple shifts to maintain continuity of care.

NSP - ACADEMIC FOUNDATION

arXiv:1904.12139v2 [quant-ph] 17 Jun 2019

Application of Quantum Annealing to Nurse Scheduling Problem

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Abstract

Quantum annealing is a promising heuristic method to solve combinatorial optimization problems, and efforts to quantify performance on real-world problems provide insights into how this approach may be best used in practice. We investigate the empirical performance of quantum annealing to solve the Nurse Scheduling Problem (NSP) with hard constraints using the D-Wave 2000Q quantum annealing device. NSP seeks the optimal assignment for a set of nurses to shifts under an accompanying set of constraints on schedule and personnel. After reducing NSP to a novel Ising-type Hamiltonian, we evaluate the solution quality obtained from the D-Wave 2000Q against the constraint requirements as well as the diversity of solutions. For the test problems explored here, our results indicate that quantum annealing recovers satisfying solutions for NSP and suggests the heuristic method is sufficient for practical use. Moreover, we observe that solution quality can be greatly improved through the use of reverse annealing, in which it is possible to refine returned results by using the annealing process a second time. We compare the performance NSP using both forward and reverse annealing methods and describe how these approach might be used in practice.

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Ikeda, K., Nakamura, Y. & Humble, T.S. Application of Quantum Annealing to Nurse Scheduling Problem. Sci Rep 9, 12837 (2019). https://doi.org/10.1038/s41598-019-49172-3

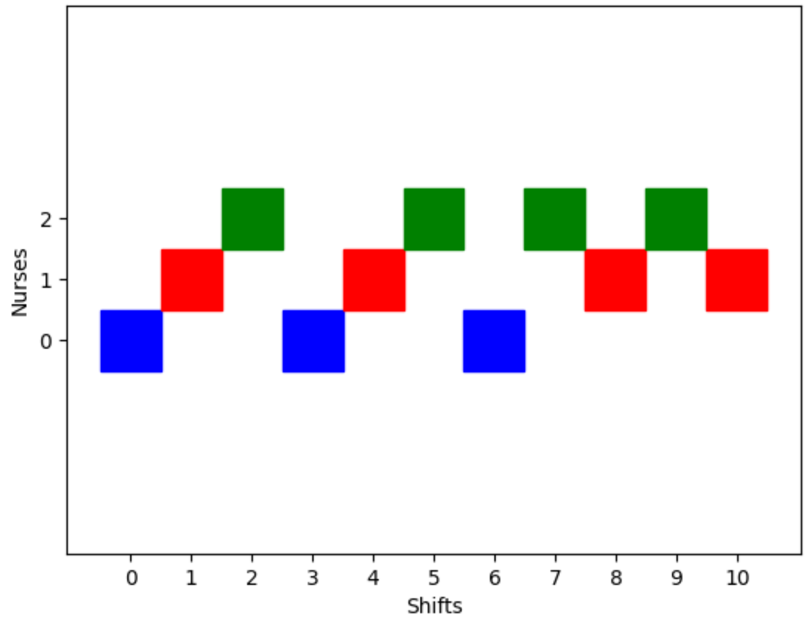
NSP - QUANTUM IMPLEMENTATION

```
# Overall model variables: problem size
# binary variable q_nd is the assignment of nurse n to day d
n_nurses = 3      # count nurses n = 1 ... n_nurses
n_days = 11       # count scheduling days as d = 1 ... n_days
size = n_days * n_nurses

# Parameters for hard nurse constraint
# a is a positive correlation coefficient for implementing the hard nurse
# constraint - value provided by Ikeda, Nakamura, Humble
a = 3.5

# Parameters for hard shift constraint
# Hard shift constraint: at least one nurse working every day
# Lagrange parameter, for hard shift constraint, on workforce and effort
lagrange_hard_shift = 1.3
workforce = 1     # Workforce function W(d) - set to a constant for now
effort = 1        # Effort function E(n) - set to a constant for now

# Parameters for soft nurse constraint
# Soft nurse constraint: all nurses should have approximately even work
#                        schedules
# Lagrange parameter, for shift constraints, on work days is called gamma
# in the paper
# Minimum duty days 'min_duty_days' - the number of work days that each
# nurse wants
# to be scheduled. At present, each will do the minimum on average.
# The parameter gamma's value suggested by Ikeda, Nakamura, Humble
lagrange_soft_nurse = 0.3      # Lagrange parameter for soft nurse, gamma
preference = 1                 # preference function - constant for now
min_duty_days = int(n_days/n_nurses)
```



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