



**Computational Intelligence**

**Course code: DS313/DS351**  **Resource Management / Assignment problem:**

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1. Introduction to linear programing:
   1. What does linear programing mean?

It’s a way of determining the optimal solutions to achieve the required objectives using limited resources such as labor, raw materials, money, demand, or machines.

The objective of functions can be maximizing the profit or the usage or minimizing the total cost or minimizing the capital.

* 1. components of linear programming:
     1. objective function:

the function that needs to be optimized.

* + 1. decision variables:

the values that determine the solution of the problem.

* + 1. constraints:

The set of simultaneous linear equations or inequalities that the problem is subject to.

* 1. important rules to formulate the linear mathematical problem:
     1. We have first to define the objective we want to achieve well maximization or minimization.
     2. Make sure that there is only a finite number of decision variables.
     3. make sure that there are at least some resources in limited supply.
     4. make sure that all elements are quantifiable.
     5. make sure that all decision variables are non-negative.
     6. make sure that both objective function and constraints are linear or inequalities.
     7. make sure that there is an alternative course of action to choose from.
  2. steps to solve linear programming problems:
     1. identification of decision variables and assigning symbols to them.
     2. representation of it as linear function of decision variables.
     3. identification of all constraints in the problem and express it as linear equation or inequalities of decision variables.
     4. Optimization of the objective function mathematically.
  3. importance of linear programming:
     1. Linear programming can solve multidimensional problems.
     2. It improves decisions quality by calculating profit and cost.
     3. It maximizes productive resources utilization.
     4. It highlights bottlenecks in production processes.
     5. It can revaluate basic plan.
  4. applications of linear programming:

it’s used widely in many aspects such as:

* + 1. engineering:

optimize using of resources in the manufacturing and production industries to maximize profit.

* + 1. logistics:

It is used for calculating the shortest route, travel times and pricing strategies.

* + 1. agriculture:

It is used for determining which crops to grow and how much to grow to increase the revenue.

* + 1. food industry:

it helps health managers and nutritionists plan dietary needs.

* + 1. energy sector:

it’s used for optimization of the electric load the shortest distribution lines, and the electrical power grid design.

* + 1. Programming and Data Science.
    2. Personnel management.
    3. Marketing management.
    4. Production management.
    5. Military application.
    6. Financial management.
  1. barriers for linear programing:
     1. in real life not all objectives are clearly defined.
     2. In linear programing models time and uncertainty not considered.
     3. In real life situations sometimes parameters that appear in the model aren’t known and aren’t constant.
     4. In real life organizations can’t take into considerations factors like weather, human behavior.
     5. In real life problem arise with multiple objectives better than single objective.

1. Nonlinear programming:
   1. What does nonlinear programming mean?

It’s solving optimization problems which their constraints and objective function is nonlinear.

* 1. types of nonlinear programing:
     1. unconstrainted nonlinear programing:

involves finding a vector x that is a local minimum to the nonlinear scalar function f(x). Quasi-Newton, Nelder Mead, and Trust-region are some common unconstrained nonlinear programming algorithms.

* + 1. constrained linear programming:

involves finding a vector x that minimizes a nonlinear function f(x) subject to one or more constraints. Interior-point, sequential quadratic programming, and trust region reflective are some common constrained nonlinear programming algorithms.

1. Resource\management assignment problem:

Resource management and assignment problems can be mathematically represented using linear or nonlinear programming formulations depending on the nature of the problem and the available resources.

Linear Programming Formulation:

In linear programming, the objective function and the constraints are all linear. A typical resource management problem can be formulated as follows:

Minimize or maximize:

Z = c1x1 + c2x2 + … + cnxn,

Subject to the constraints:

a11x1 + a12x2 + … + a1nxn ≤ b1

a21x1 + a22x2 + … + a2nxn ≤ b2

…

am1x1 + am2x2 + … + amnxn ≤ bm

where xi represents the amount of resource i assigned to a particular task, ci is the cost or benefit associated with resource i, aij represents the consumption or production of resource i for task j, and bj is the limit on the available resource i.

Nonlinear Programming Formulation:

In nonlinear programming, the objective function and/or the constraints involve nonlinear functions such as polynomial, exponential, trigonometric, or logarithmic functions. A typical nonlinear resource management problem can be formulated as follows:

Minimize or maximize:

Z = f (x1, x2, ..., xn)

Subject to the constraints:

g1(x1, x2, …, xn) ≤ 0

g2(x1, x2, …, xn) ≤ 0

…

gm(x1, x2, …, xn) ≤ 0

h1(x1, x2, …, xn) = 0

h2(x1, x2, …, xn) = 0

…

hr (x1, x2, …, xn) = 0

where f is the nonlinear objective function, gi are the inequality constraints, and hi are the equality constraints.

1. Differential algorithms
   1. differential algorithm’s introduction:

Differential Evolution (DE) is a population-based optimization algorithm that is used to solve a variety of resource management problems including assignment problems, scheduling problems, resource allocation problems, and others. The DE algorithm works by maintaining a population of solutions that evolves over time by iteratively generating and testing new candidate solutions. The key steps involved in the DE algorithm are.

4.1.1 Initialization: Generate an initial population of candidate solutions randomly or using heuristics.

4.1.2 Mutation: Generate a new candidate solution by perturbing the population using differential vectors.

4.1.3 Crossover: Combine the new candidate solution with a randomly selected individual from the population to create a trial solution.

4..1.4 Selection: Compare the trial solution with the individual in the population using a fitness function and select the better of the two.

4.1.5 Reproduction: Replace the worst individual in the population with the selected trial solution.

4.1.6 Termination: Stop the algorithm when a stopping criterion is met such as a maximum number of iterations or a minimum acceptable level of fitness.

DE algorithms are effective for solving resource management problems because they are simple to implement, require minimal parameter tuning, and can handle both linear and nonlinear constraints. DE algorithms have been applied in various fields including engineering design, logistics, finance, and others to optimize complex allocation and scheduling problems where other methods have failed

* 1. basic steps of differential algorithm:

4.2.1 Initialization: A population of solutions is randomly generated.

4.2.2 Mutation: A new solution is generated by randomly mutating one or more of the existing solutions.

4.2.3 Crossover: The new solution is crossed over with one or more of the existing solutions to generate a new set of solutions.

4.3.4 Evaluation: The new solutions are evaluated to determine their fitness.

4.3.5 Selection: The best solutions are selected to form the next generation of solutions.

1. Linear and nonlinear programming in resource management:

Linear and nonlinear mathematical formulations are used in resource management to help decision-makers make optimal decisions about how to allocate resources. Linear formulations are simpler to solve, but they may not be realistic in all cases. Nonlinear formulations are more complex, but they can be more realistic and can provide better solutions.

One example of a linear mathematical formulation for resource management is the transportation problem. In this problem, a company has a number of sources of supply and a number of destinations for its products. The company wants to minimize the cost of shipping its products from the sources to the destinations, subject to the constraints that the total amount of product shipped from each source must equal the total amount of product received at each destination.

Another example of a linear mathematical formulation for resource management is the assignment problem. In this problem, a company has several tasks that need to be completed and a number of workers who can complete the tasks. The company wants to assign the tasks to the workers in such a way that the total cost of completing the tasks is minimized.

Nonlinear mathematical formulations can be used to model more complex resource management problems. For example, a company may want to minimize the cost of producing a product while also meeting certain quality requirements. This problem can be modeled as a nonlinear programming problem.

Here are some examples of nonlinear mathematical formulations for resource management:

•Production planning: A company wants to minimize the cost of producing a product while also meeting certain demand requirements.

•Inventory management: A company wants to minimize the cost of holding inventory while also meeting customer demand.

•Capacity planning: A company wants to determine the optimal amount of capacity to invest in to meet future demand.

•Risk management: A company wants to minimize the risk of losing money due to unexpected events.

Mathematical formulations can be used to help decision-makers make optimal decisions about how to allocate resources. However, it is important to note that these formulations are only models of the real world. The results of these models should be used in conjunction with other information, such as expert judgment, to make decisions.

Differential Evolution (DE) is a metaheuristic algorithm that can be used to solve a wide variety of optimization problems, including resource management and assignment problems. DE is a population-based algorithm, which means that it starts with a population of solutions and then iteratively improves the solutions in the population.

1. Importance of differential algorithms:

DE has been shown to be effective in solving a wide variety of resource management and assignment problems. For example, DE has been used to solve problems such as:

•Production planning: DE has been used to minimize the cost of producing a product while also meeting certain demand requirements.

•Inventory management: DE has been used to minimize the cost of holding inventory while also meeting customer demand.

•Capacity planning: DE has been used to determine the optimal amount of capacity to invest in to meet future demand.

•Risk management: DE has been used to minimize the risk of losing money due to unexpected events.

1. Advantages of using DE to solve resource management and assignment problems:

DE is a powerful tool that can be used to solve a wide variety of resource management and assignment problems. However, it is important to note that DE is not a panacea and may not be the best solution for all problems. It is important to evaluate DE on a case-by-case basis to determine if it is the best solution for a particular problem.

•DE is a simple and easy-to-implement algorithm.

•DE is a robust algorithm that can be used to solve a wide variety of problems.

•DE is a versatile algorithm that can be used to solve both continuous and discrete problems.

•DE is a computationally efficient algorithm that can solve problems with large search spaces.

1. disadvantages of using DE to solve resource management and assignment problems:

•DE may not converge to the optimal solution.

•DE may be sensitive to the choice of parameters.

•DE may not be as efficient as other algorithms for some problems.

1. mathematical model for resource management / assignment topic:

Objective function:

The objective of resource management is to minimize the total cost of resources. The total cost of resources is the sum of the costs of all resources used, including the cost of acquiring the resources, the cost of maintaining the resources, and the cost of using the resources.

Constraints:

The following constraints must be satisfied:

The total amount of resources used must be less than or equal to the total amount of resources available.

Each resource must be used for a specific task.

Each task must be assigned to a specific resource.

The total cost of resources used must be less than or equal to a specified budget.

The following are some examples of constraints that may be relevant to a specific resource management problem:

The total amount of time that each resource can be used must be less than or equal to the total amount of time that the resource is available.

The total amount of power that each resource can use must be less than or equal to the total amount of power that the resource is available.

The total amount of space that each resource can use must be less than or equal to the total amount of space that the resource is available.

The specific constraints that are relevant to a particular resource management problem will depend on the specific resources and tasks involved.

Solution:

The objective function and constraints can be solved using a variety of methods, including linear programming, integer programming, and mixed-integer programming. The specific method that is used will depend on the specific problem and the desired level of accuracy.

The solution to the resource management problem will provide a set of assignments for resources to tasks that minimizes the total cost of resources. The solution can be used to make decisions about how to allocate resources to tasks in order to minimize costs.

* 1. 3 mathematical model for resource management/assignment topic:

Model 1:

The objective of this model is to minimize the total cost of resources. The total cost of resources is the sum of the costs of all resources used, including the cost of acquiring the resources, the cost of maintaining the resources, and the cost of using the resources.

The following constraints must be satisfied:

The total amount of resources used must be less than or equal to the total amount of resources available.

Each resource must be used for a specific task.

Each task must be assigned to a specific resource.

The total cost of resources used must be less than or equal to a specified budget.

The model can be expressed as follows:

Code snippet

Minimize:

Z = Σr(Cr \* Nr)

Subject to:

Σr(Nr) <= R

Nr <= 1 for all r

Nr \* Tr <= B

for all r and t

Use code with caution. Learn more

where:

Z is the objective function

Cr is the cost of resource r

Nr is the number of units of resource r used

R is the total amount of resources available

t is a task

Tr is the cost of task t

B is the budget

Model 2:

The objective of this model is to minimize the total time required to complete all tasks. The total time required to complete all tasks is the sum of the times required to complete each task.

The following constraints must be satisfied:

The total amount of resources used must be less than or equal to the total amount of resources available.

Each resource must be used for a specific task.

Each task must be assigned to a specific resource.

The total time required to complete all tasks must be less than or equal to a specified deadline.

The model can be expressed as follows:

Code snippet

Minimize:

Z = Σt(Tt)

Subject to:

Σr(Nr) <= R

Nr <= 1 for all r

Nr \* Tr <= B

for all r and t

Σt(Tt) <= D

Use code with caution. Learn more

where:

Z is the objective function

Tt is the time required to complete task t

D is the deadline

Model 3:

The objective of this model is to maximize the total number of tasks that can be completed within a specified time period. The total number of tasks that can be completed within a specified time period is the sum of the number of tasks that can be completed in each time period.

The following constraints must be satisfied:

The total amount of resources used must be less than or equal to the total amount of resources available.

Each resource must be used for a specific task.

Each task must be assigned to a specific resource.

The total number of tasks that can be completed within a specified time period must be greater than or equal to a specified minimum.

The model can be expressed as follows:

Code snippet

Maximize:

Z = Σt(Nt)

Subject to:

Σr(Nr) <= R

Nr <= 1 for all r

Nr \* Tr <= B

for all r and t

Σt(Nt) >= M

Use code with caution. Learn more

where:

Z is the objective function

Nt is the number of tasks that can be completed in time period t

M is the minimum number of tasks that must be completed

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