Emergency Goods Distribution Model over Finite-Time Interval using Genetic Algorithm

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1. Introduction

- There are victims who didn’t receive any donations.
- Manually distribution management is difficult to operate.
- Computer can be help to distribute donations without bias.

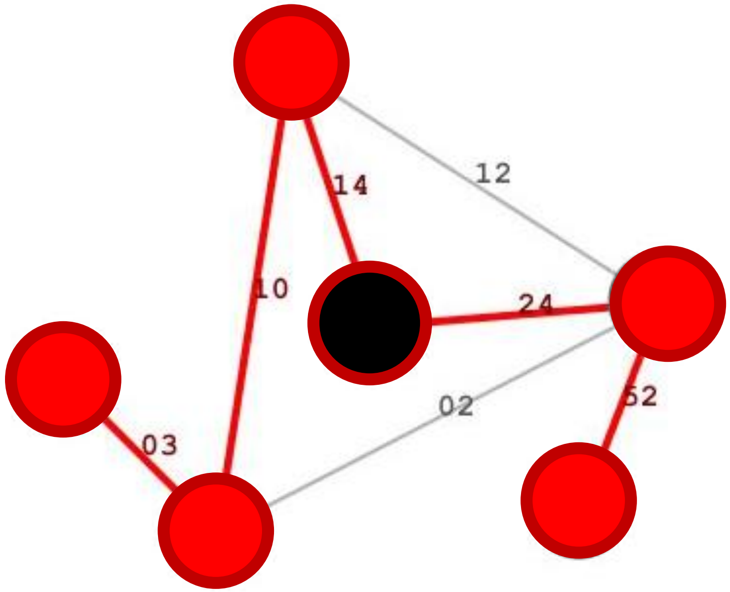
2. Problem Description

There are 3 important things the problem:

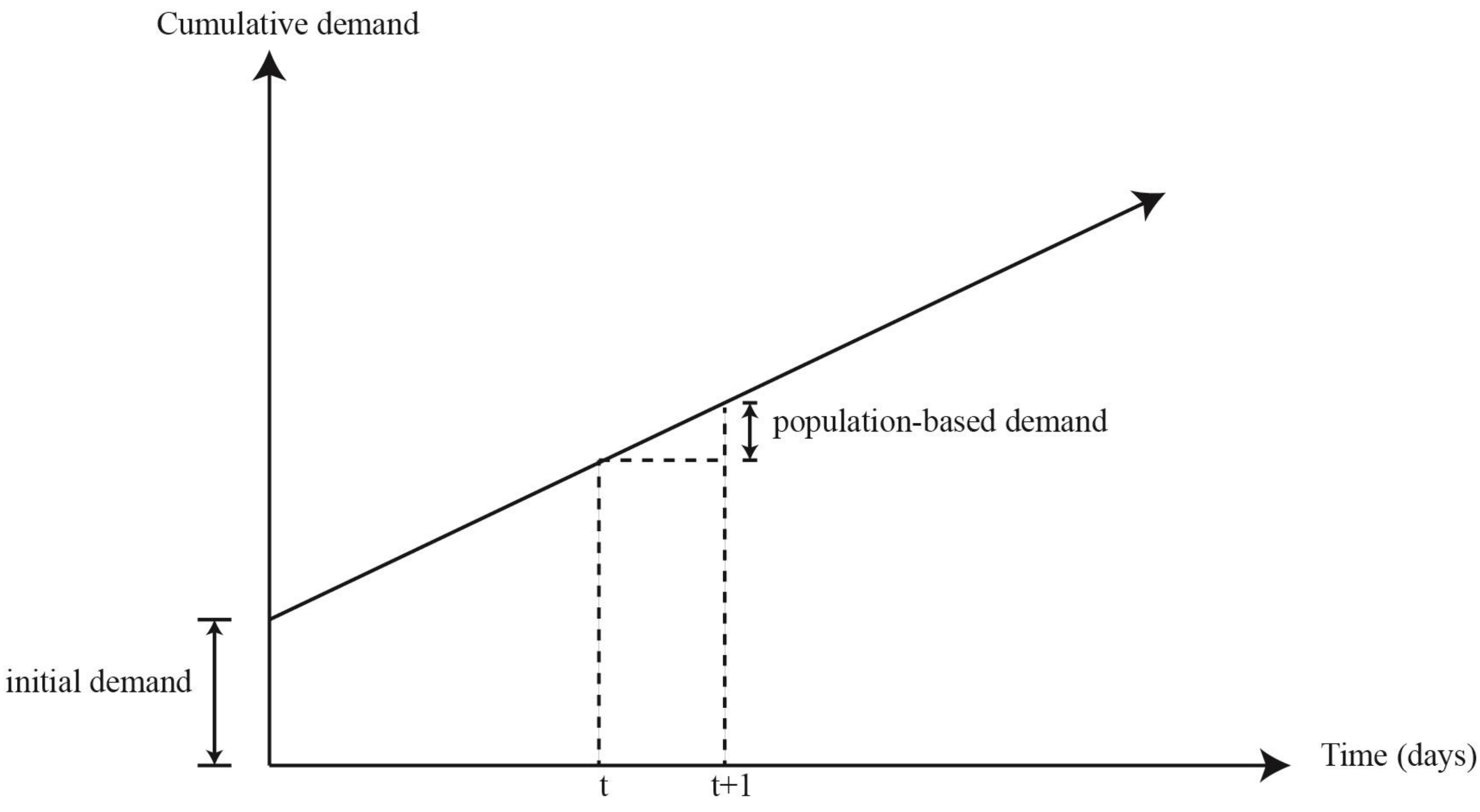
- Disaster area
- Demand of victims
- Donations

2.1 Disaster Area

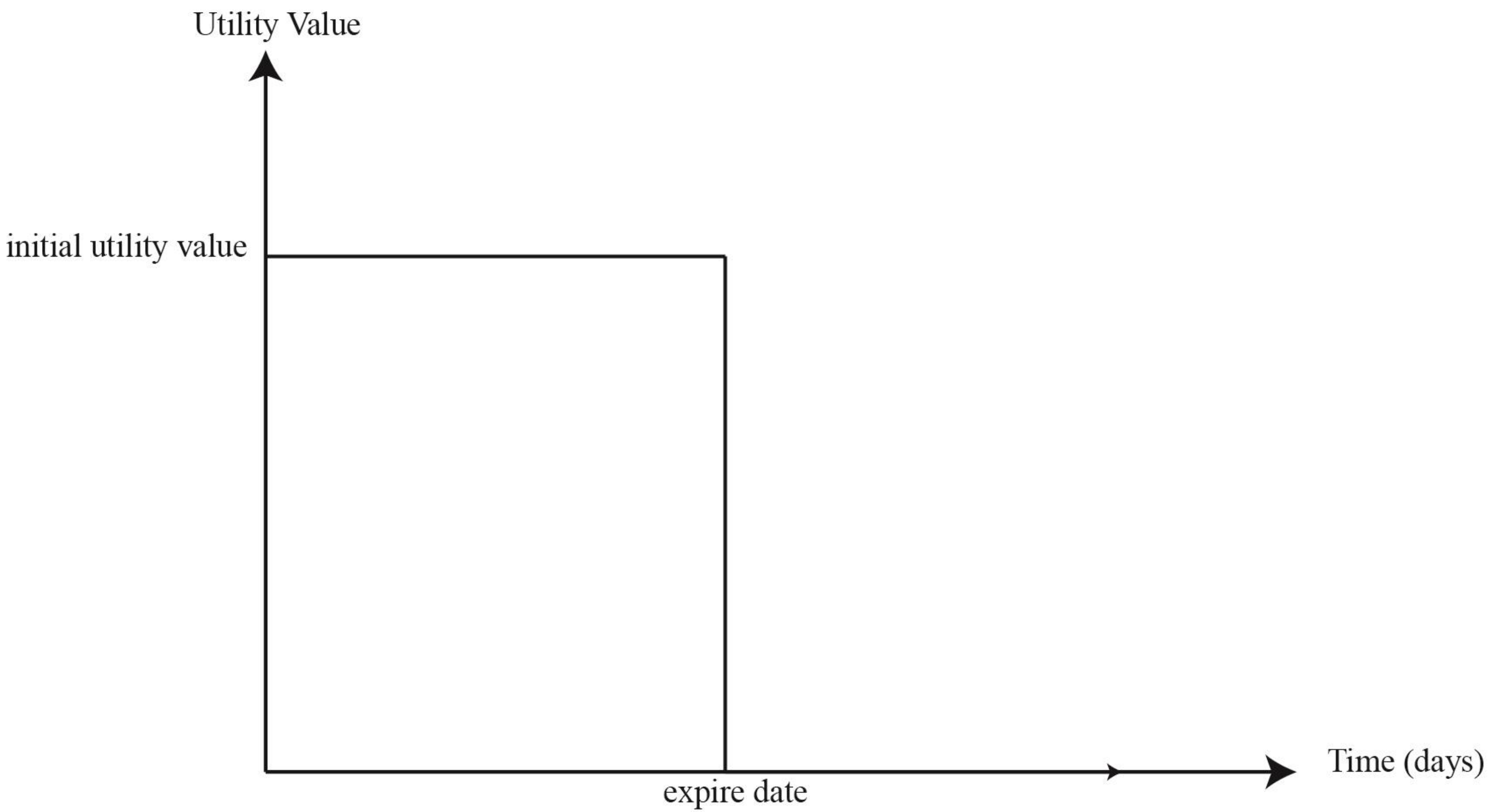
- Node = Distribution center + Cities
- Edge = Connection between two nodes
- Weight = Time required to travel on edge



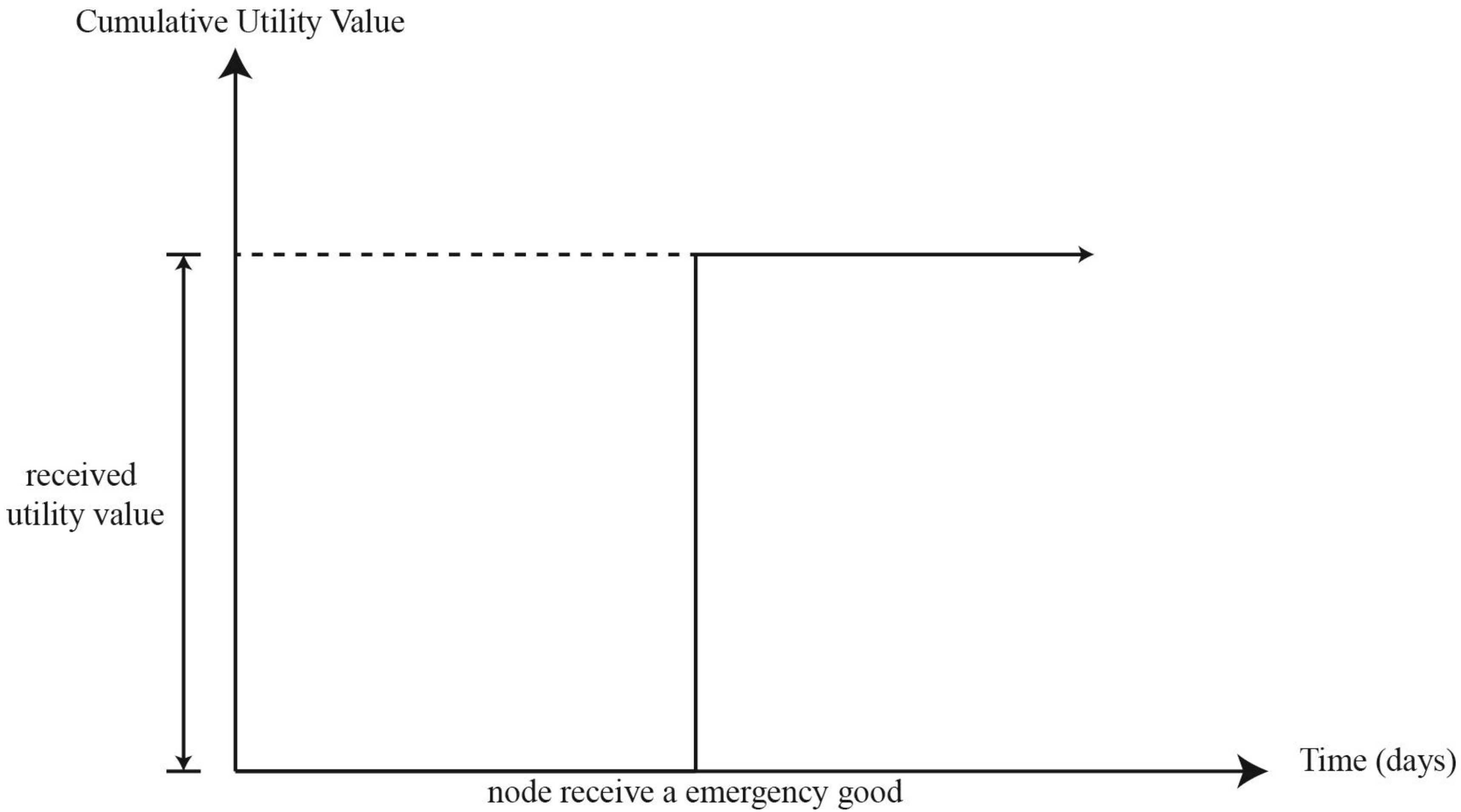
2.2 Demand of victims



2.3 Donations



2.3 Donations (cont'd)



2.4 Assumptions

- Every day distribution center receive donations.
- MUST distribute all received donations in same day.
- NOT know anything about donations received in the future.
- CAN reassign destination to donations during transportation stage.
- NOT consider transportation cost and vehicles.

2.5 Objective Function

- Every nodes has equal ratio between its cumulative utility value and its cumulative demand.

EXAMPLE

Node	Cumulative Utility Value	Cumulative Demand	Ratio
1	70	100	0.7
2	70,000	100,000	0.7
3	7	10	0.7

2.5 Objective Function (cont'd)

$$\min_{(x_1,x_2,\dots,x_n)\in(\mathbb{R}_0^+)^n} \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n}}$$

$$\min_{(x_1,x_2,\dots,x_n)\in(\mathbb{R}_0^+)^n} \frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2$$

$$\text{minimize } f = \frac{1}{T}\sum_{t=1}^{T} p(t)$$

$$p(t) = \sum_{u\in V(G)}\left(R_u(t) - \frac{1}{|V(G)|}\sum_{u\in V(G)} R_u(t)\right)^2$$

3. Genetic Algorithm (GA)

There are 3 main parts in GA:

- Chromosome Encoding System
- Fitness Function
- Implementation Detail

3.1 Chromosome Encoding System

- A chromosome is represented by an integer vector.
- For a vector x, x_i is destination of donation index i.

EXAMPLE

3	1	3	…	0

- 1st Donation go to 3rd Node
- 2nd Donation go to 1st Node
- 3rd Donation go to 3rd Node
- and so on

3.2 Fitness Function

$$\text{Fitness}(\bar{\chi}) = -\frac{1}{T}\sum_{t=1}^{T} p(t)$$

$$\boxed{\mathrm{O}(d + T|V(G)|)}$$

$$p(t) = \sum_{u \in V(G)} \left(R_u(t) - \frac{1}{|V(G)|} \sum_{u \in V(G)} R_u(t) \right)^2$$

$$R_u(t) = \begin{cases} 0 & \text{if} \quad t < t_{T(G)}\left(S_{u,1,1}, S_{u,1,2}, u\right) \\ \min\left(1, \frac{1}{D_u(t)} \sum_{j=1}^{i-1} b_{S_{u,j,1}, S_{u,j,2}}\right) & \text{if} \quad t \in \left[t_{T(G)}\left(S_{u,i-1,1}, S_{u,i-1,2}, u\right), t_{T(G)}\left(S_{u,i,1}, S_{u,i,2}, u\right)\right);\ \exists i \in [2, |S_u|] \\ \min\left(1, \frac{1}{D_u(t)} \sum_{j=1}^{|S_u|} b_{S_{u,j,1}, S_{u,j,2}}\right) & \text{if} \quad t \geq t_{T(G)}\left(S_{u,|S_u|,1}, S_{u,|S_u|,2}, u\right) \end{cases}$$

3.3 Implementation Detail

- Genetic Operators
  - K-Tournament Selection
  - Uniform Crossover
  - Random Resetting
- Termination Criteria
  - Maximum Evolutionary Generation
  - Maximum Evolutionary Non-Improved Generation
  - Found Optimal Strategy

Have you realized any problems?

You can reassign destination to donations during transportation stage.

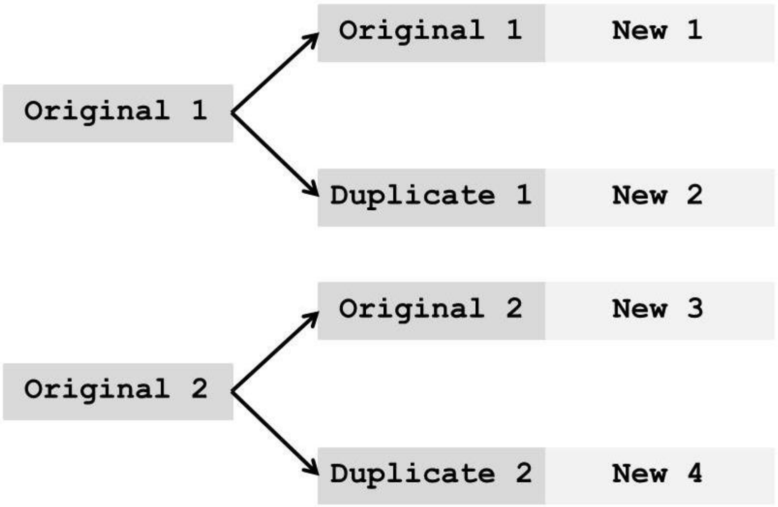
3.4 Dynamic Length Chromosome Encoding System

- Chromosome at different time has different length.
- Chromosome the same time has the same length.
- $x_{t,j}$ is destination of donation index j that distribution center received at time t.

$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	$x_{1,4}$	...	x_{t,N_t}

3.5 Population Re-Initialization

- Extend the existing chromosomes to encode new strategy.
- Every chromosome in the previous time is replicated before new gene additions.



4. Discussion

- Not enough donations
  - Node with demand more than average tend to receive more donations than less ones.
- Few nodes take time to reach
  - Algorithm tends to send donations to them first to deal with transportation duration.
- Few nodes with extremely high demand
  - Distribution center tends to ignore them. (not enough donations)
  - Algorithm can distribute donations well. (otherwise)

5. Future Work

Model can be improved in 3 issues:

- Dynamic Graph
- Dynamic Demand
- Financial Constraint

5.1 Dynamic Graph

- Node insertion
- Node deletion
- Edge insertion
- Edge deletion
- Weight modification
- Change distribution center

5.2 Dynamic Demand

$$D_u(t) = r_u t + z_u$$

$$\downarrow$$

$$D_u^{(k)}(t) = r_{u,k}\big(\max\big(0, t - T_{u,k} + 1\big)\big) + \sum_{j=1}^{k} r_{u,j-1}\big(\max\big(0, \min\big(t, T_{u,j}\big) - T_{u,j-1}\big)\big) + z_u$$

5.3 Financial Constraint

$$\min f = \frac{1}{T}\sum_{t=1}^{T} p(t) - C$$

where

$$C = \begin{cases} \lambda \log\left(\Phi - \sum_{t=1}^{T} c(t)\right) & \text{if} \quad \Phi > \sum_{t=1}^{T} c(t) \\ -\infty & \text{if} \quad \Phi \leq \sum_{t=1}^{T} c(t) \end{cases}$$

Research Contribution

- From simulation, the proposed optimization model has high potential to be used to distribute donations.
- *The dynamic length chromosome encoding system and population re-initialization step are innovative way to solve other optimization problems.*