Optimum Strategies of Container Inspection at Port-of-Entry

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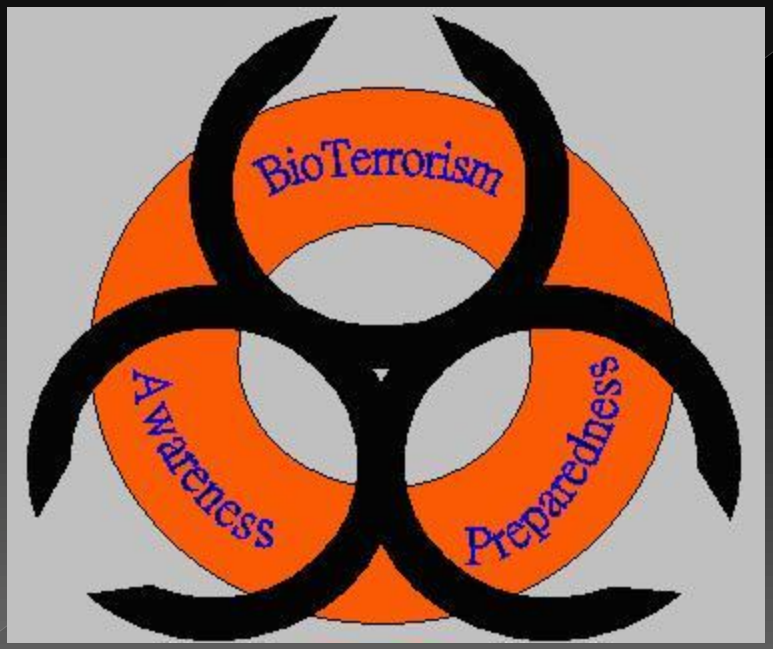
Introduction

- Increase in in trade agreements and the growth of the world economy has increased maritime traffic
- Trade globalization and outsourcing goods has increased overall trade.
- More than 95% of the non-North American foreign trade arrives into US ports by ship

Safe Guards Necessary

There is a need to be able to detect dangerous and undesirable content: nuclear material, biological agents, drugs, weapons, contaminated goods, etc.

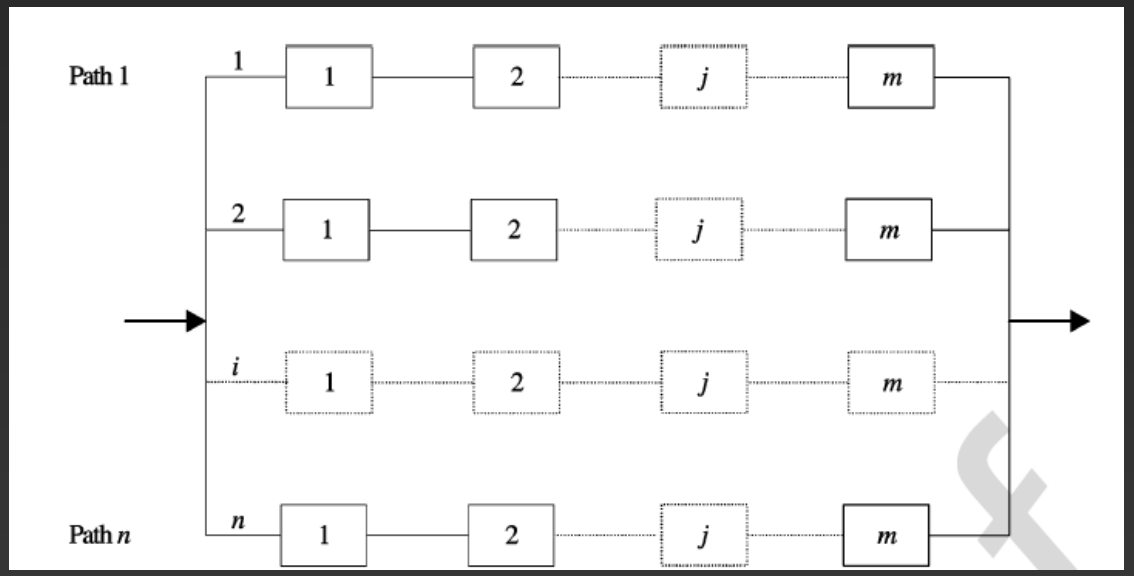


Port –of-Entry Problem Basics

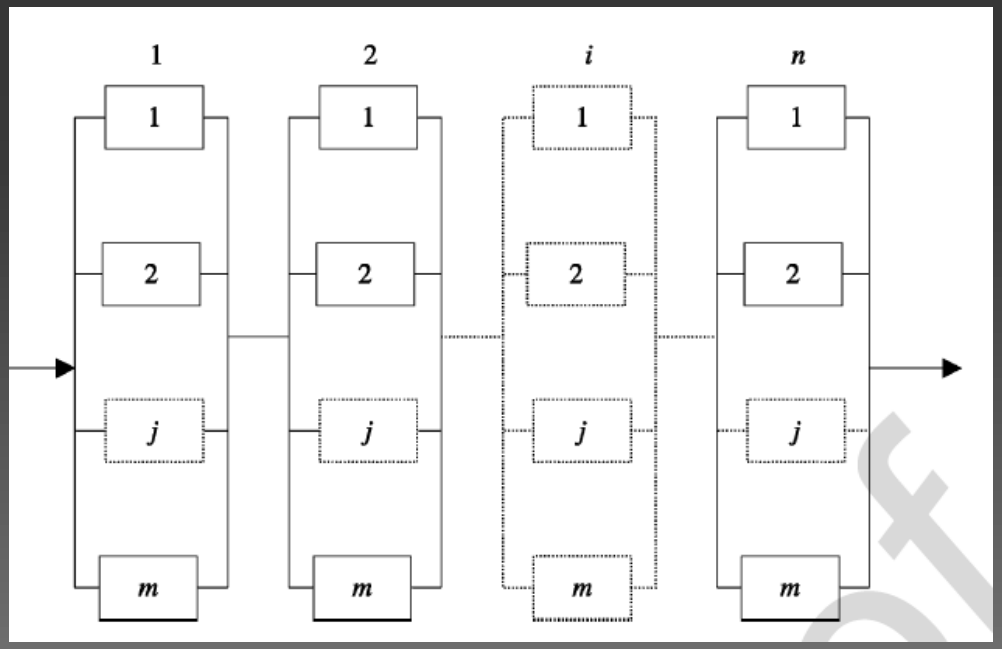
- Inspection system is interpreted as a collection of stations
- Each station has a sensor that tests for presence of a specific attribute
- Stations are assumed to be independent
- If container passes inspection stations: acceptable cargo
- If container does not pass inspection station: illegal cargo
  - Costly and time consuming
- Methods of Inspection:
  Parallel, Series, Parallel-Series, Series-Parallel

Specific Types of Inspection

Parallel Series



Series Parallel



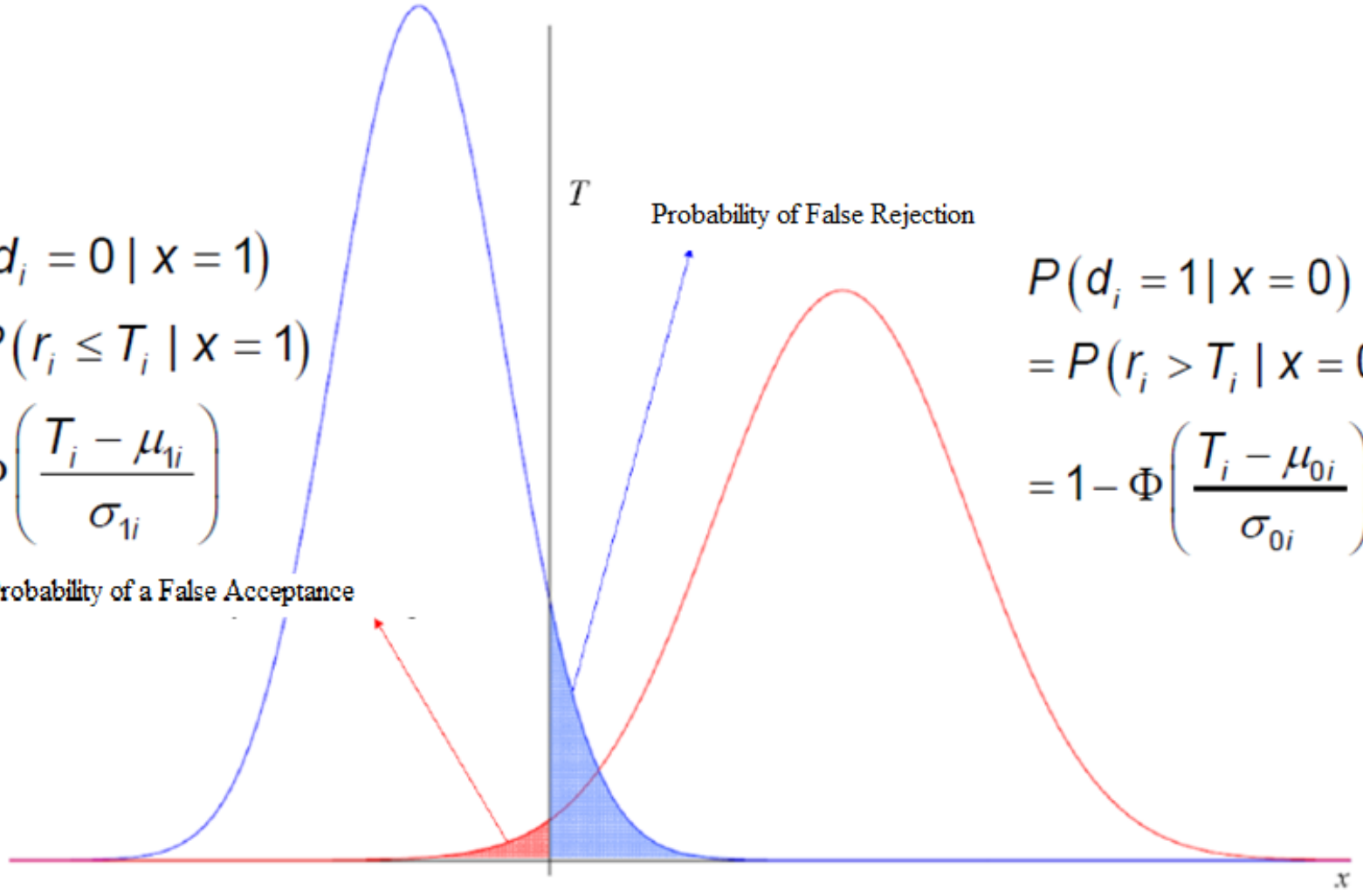
Modeling Approach

- Assume the unit's true state (x) is 0 (acceptable) or 1 (illegal)
- Assume prior distribution of previous suspicious containers is known: $\pi = P(x=1) = 1 - P(x=0)$
- A container attribute value comes from a mixture of two normal distributions, depending on the unit's true state: given by r.
- Let r represent the sensor reading from a unit: $\mu_0 \neq \mu_1$
  - For $x = 0 \sim \text{Norm}(\mu_0, \sigma_0^2)$
  - For $x = 1 \sim \text{Norm}(\mu_1, \sigma_1^2)$
- For some threshold value, T_i at station i
  - If measure $r_i > T_i$ then the decision for station i is $d_i = 1$.
  - If measure $r_i \leq T_i$ then the decision for station i is $d_i = 0$.

Possible Errors

$$P(d_i = 0 \mid x = 1) = P(r_i \le T_i \mid x = 1) = \Phi\left(\frac{T_i - \mu_{1i}}{\sigma_{1i}}\right)$$

$$P(d_i = 1 \mid x = 0) = P(r_i > T_i \mid x = 0) = 1 - \Phi\left(\frac{T_i - \mu_{0i}}{\sigma_{0i}}\right)$$



Cost, Cost, Cost

- Misclassification costs:
  - C_{fa} = cost of false acceptance
  - C_{fr} = cost of false rejection
- Total Misclassification costs:
  - $C_f = \pi \, PFA \, C_{fa} + (1- \pi) \, PFR \, C_{fr}$

More cost!

- c_i = cost of using sensor i
- Probability of passing sensor i
  - $p_i = P(d_i = 0) = P(d_i = 0|x=0)\ (1- \pi) + P(d_i = 1|x=0)(\pi)$
    $= (1- \pi)\ \Phi[(T_i – \mu_{0i})/ \sigma_{0i}] + (\pi)\ \Phi[(T_i – \mu_{1i})/ \sigma_{1i}]$
- Probability of failing sensor i
  - $q_i = 1 - p_i$

Time to Optimize

- The sequence in which stations are visited affects the expected cost of inspection
- A sequence which minimizes this cost is known as an optimal sequence

Multiple Objectives!

- Minimize Total Cost: $C_{Total} = C_i + C_{misclass}$
- Other factors are also important.
- Need to take into account total time, $T_{Total,}$ at each inspection station so delays and further loss in costs do not occur. The more time you have, the lower the threshold (so more containers can be inspected)
- Goal: minimize sequence, threshold = $\{C_{Total}, T_{Total}\}$
- Must use weights to balance: C_{Total}, T_{total}
  - $C_{w1w2}(S,T) = w_1 C_{Total}\, I + w_2 T_{Total}$, $w_1 + w_2 = 1$
  - Use Pareto optimal point to solve

Conclusions, Goals

1) Containers are given attributes and a specific risk profile (an array of information that has weights of possible risk factors)
2) To an inspection station: processing time, threshold level. Minimize!
3) Once these containers arrive, batch them accordingly to risk and non-risk (start some type of sequence)
4) Optimize by minimizing tardiness, cost, and PFA
5) Undergo protocol (start undergoing specific sequence found under optimization).

My goal is by using probability, and optimization techniques to create an algorithm through MATLAB that can create an optimal solution by using a risk profile and time based information.

Thanks!

- THANKS!
- GRACIAS!