The Weapon-Target Assignment Problem [Kline et al., 2019]

- As ↑ quantity and quality of missiles, effective allocation research emerged.
- Weapon Target Assignment (WTA) aka Missile Allocation Problem (MAP) ⇔ minimize probabiilty of a missile destroying a protected assignment
- Sometimes offense perspective OR defense perspective
- WTA → Static WTA (SWTA) or Dynamic WTA (DWTA)
- SWTA:
  input: num. of incoming missiles (targets), num. of interceptors (weapons), probabilities of destroying targets
  output: how many of each weapon type to shoot at each target
- DWTA includes time as a dimension. Two variants: two-stage and shoot-look-shoot
  - Two-stage DWTA:
    stages/input: 1. SWTA and 2. probability distribution of various kinds of targets
    output: 1. allocation of weapons and 2. how many weapons to reserve to minimize prob. of destruction
  - Shoot-kill-Shoot DWTA:
    replicates SWTA too, but enables observation of leakers: target that maybe survived the initial engagement for a subsequent engagement
    solution: allocation of weapons and reservation of weapons to rengage any leakers
- WTA is NP-Complete, so majority of solutions seek near-optimal solutions in real-time, or fast-enough solutions before the adversary reaches their goals.
- These solutions use heuristics or have exact solutions applied to variants of the WTA problem

Formulations

Notation:

- p_{ij} : the probability weaponi destroys target j
- $q_{ij}(= 1 - p_{ij})$: the probability weapon i fails to destroys target j
- V_j : the destructive value of target j

- x_{ij} : the number of weapons of type i assigned to target j
- K : the number of protected assets
- a_k : the value of asset k
- n : the number of targets
- m : the number of weapon types
- w_i : the number of weapons of type i
- c_{ij} : a cost parameter for assigning a weapon of type i to target j
- $\mathcal{F}$: the set of feasible assignments
- γ_{jk} : the probability target j destroys asset k
- s_j : the maximum number of weapons that can be assigned to target j
- t : the number of stages

  Main formulation:

$$\begin{array}{ll} \min & \sum_{j=1}^{n} V_j \prod_{i=1}^{m} q_{ij}^{x_{ij}} \\ \text{s.t.} & \sum_{j=1}^{n} x_{ij} \leq w_i, \text{ for } i = 1, \ldots, m \\ & x_{ij} \in \mathbb{Z}_+, \text{for } i = 1, \ldots, m, j = 1, \ldots, n \end{array}$$

  In English: find the best assignment of number of weapons, across all types, that minimizes the survival rate of the targets, with higher emphasis of those with more destructive value. The "such that (s.t.)" requriements indicate that we must respect our supply capacity of weapons and that we must allocate at least weapon of each type to all targets.

Applying reinforcement learning to the weapon assignment problem in air defence [Mouton et al., 2011]

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Optimization of Weapon-Target Pairings Based on Kill Probabilities [Bogdanowicz et al., 2013]

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A New Approach to Weapon-Target Assignment in Cooperative Air Combat [Chang et al., 2017]

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A Coordinated Air Defense Learning System Based on Immunized Classifier Systems [Nantogma et al., 2021]

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The state-of-the-art review on resource allocation problem using artificial intelligence methods on various computing paradigms [Joloudari et al., 2022]

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