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Search Algorithms in the Aftermath of a Disaster

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COPIOR-HORAF CONFERENCE ON

OPERATIONS/AL RESEARCH TOOLS FOR THE AFTERMATH OF A DISASTER:

THE MAJOR EARTHQUAKE IN TURKEY-SYRIA

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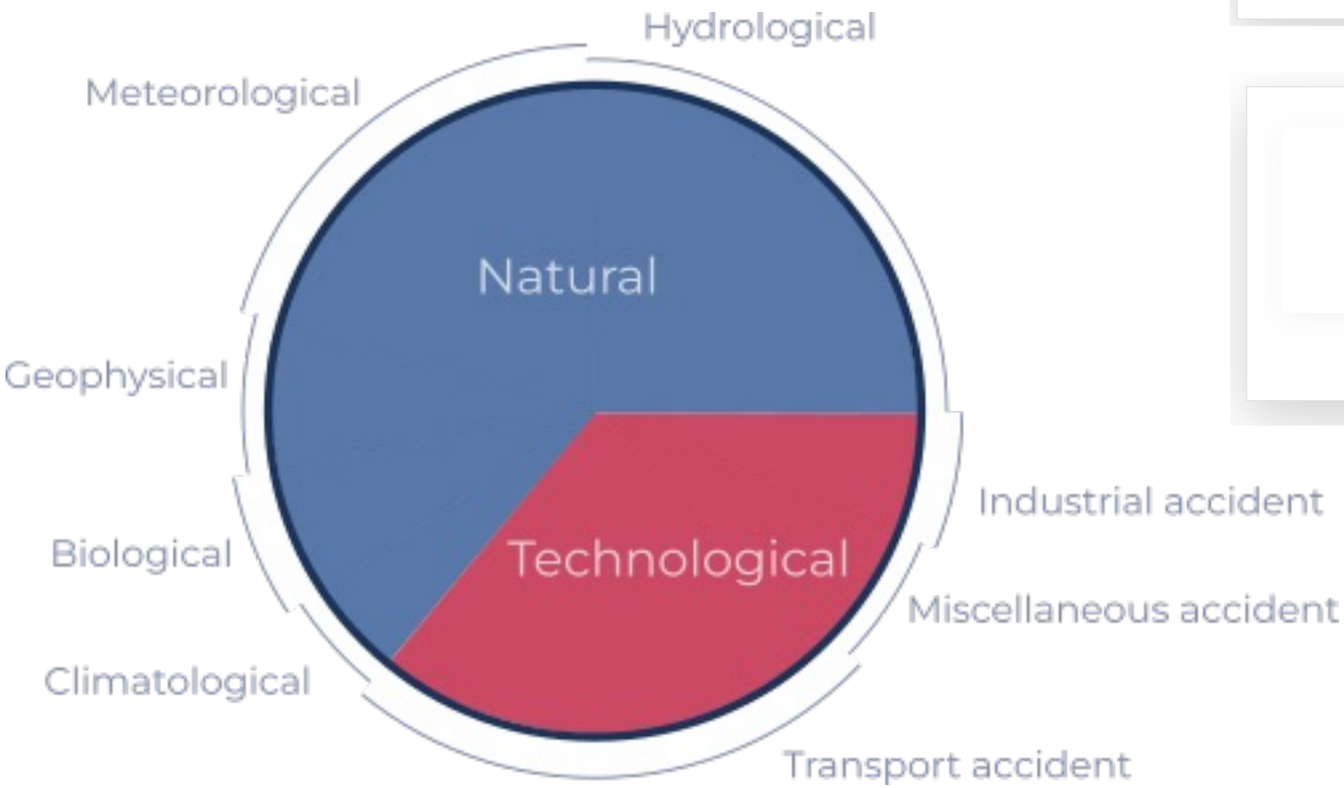
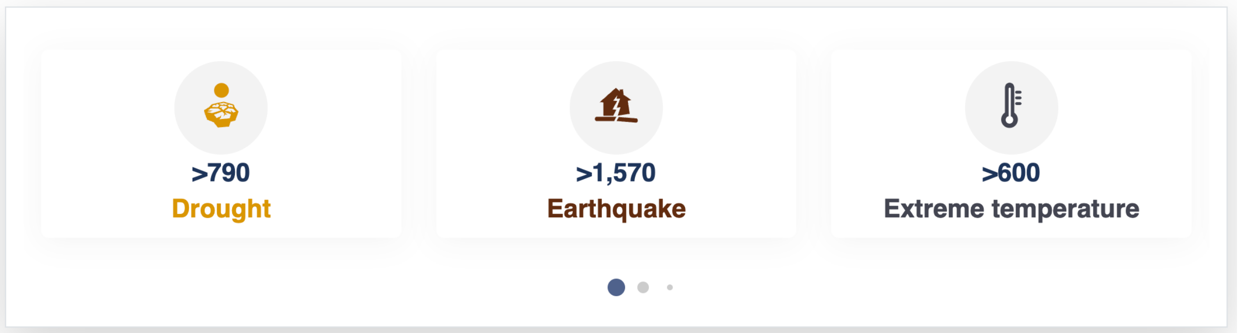
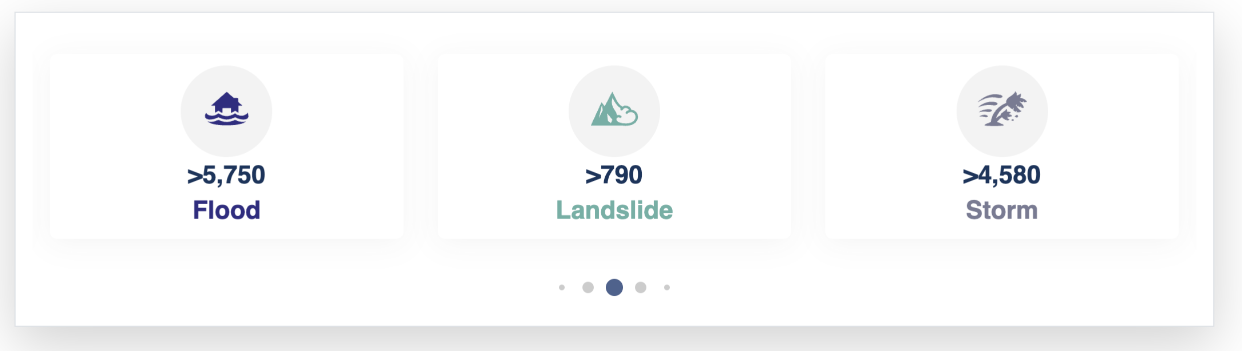
About 2/3 of disasters in EM-DAT ~ natural hazards





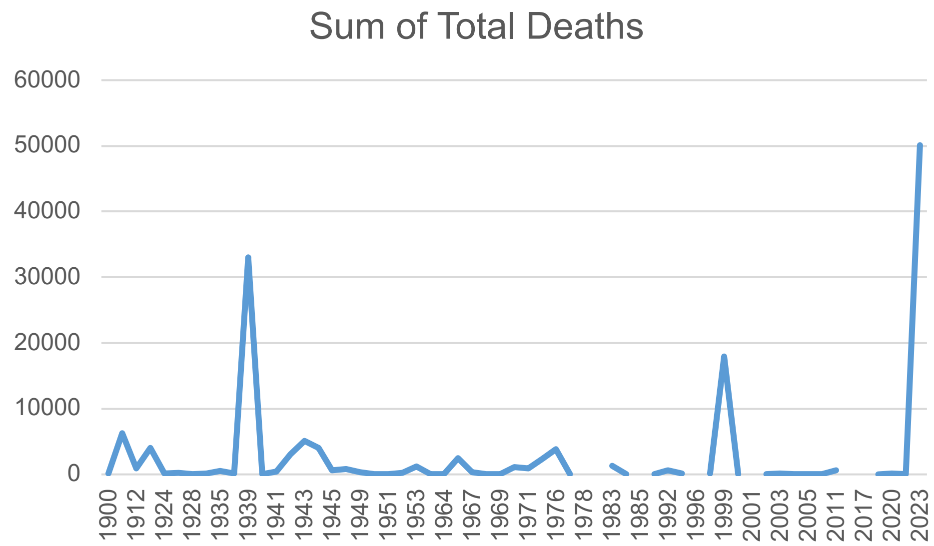


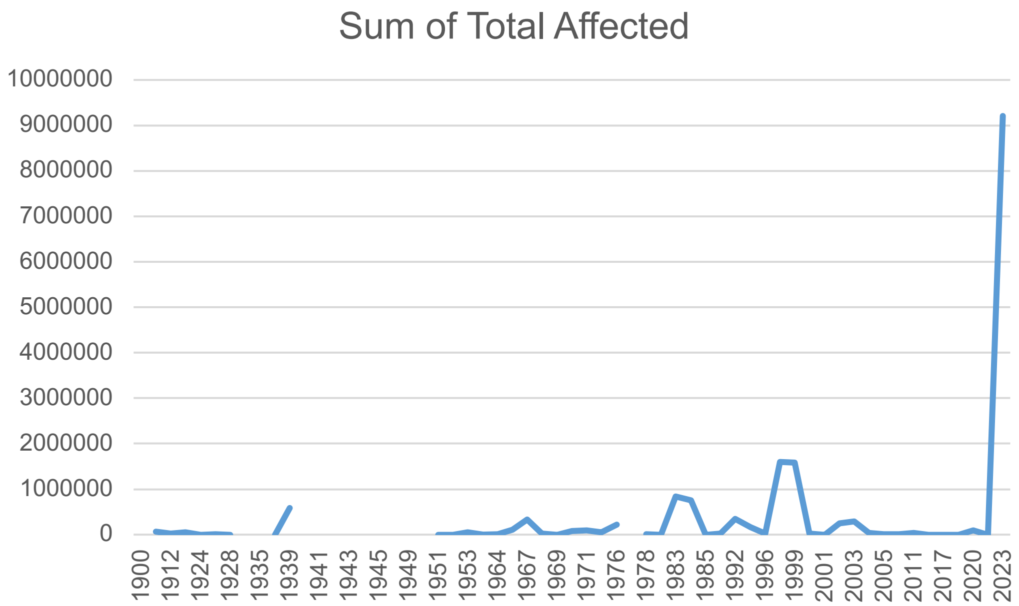
Why we need search algorithms?

- It costs to find what we are searching for.
- Lives are at risk if we do not find people in time.

Image credit: https://www.mountain.rescue.org.uk/

Earthquakes in Turkey





Source: EM-DAT

https://www.theguardian.com/world/2023/mar/06/turkey-earthquake-victims-families-still-search

https://apnews.com/article/disaster-planning-and-response-2023-turkey-syria-earthquake-earthquakes-a7ae0cf86757d238dc0dd5f6a5dd96ce

https://www.bbc.co.uk/news/world-64569943

Optimal Search and Stop Problem

JOURNAL ARTICLE

A Periodic Optimal Search

David Matula

The American Mathematical Monthly, Vol. 71, No. 1 (Jan., 1964), pp. 15-21 (7 pages)

https://doi.org/10.2307/2311296 • https://www.jstor.org/stable/2311296

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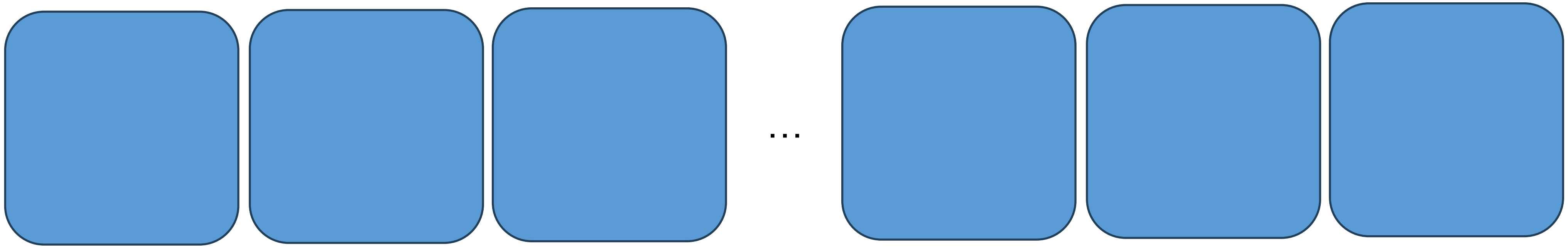
A Problem in Optimal Search and Stop

Sheldon M. Ross

Published Online: 1 Dec 1969 | https://doi.org/10.1287/opre.17.6.984

Problem Description



A finite set of possible locations, I

p_i: probability that the object is in one of these locations

c_i: cost of searching each location

a_i: probability of finding the object during the search when it is in i

Minimise the expected cost of finding the object

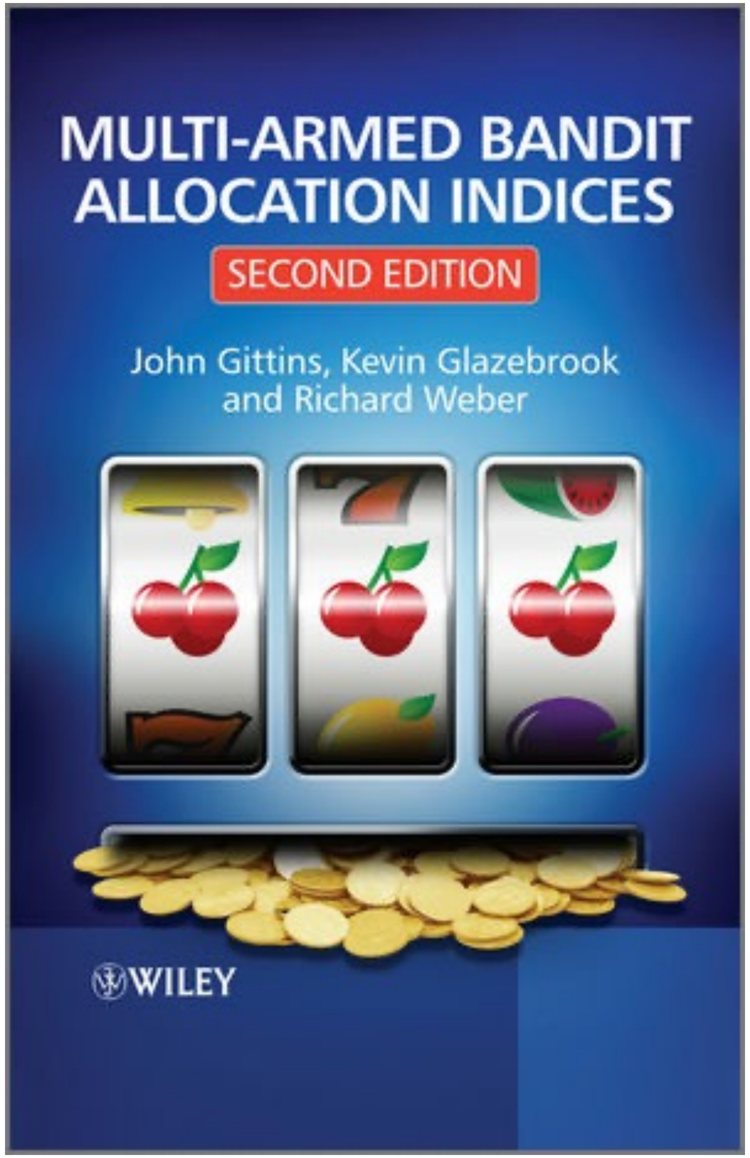
A strategy: when to search, and, if so, which box?

Multi-Armed Bandit Problem

A decision-maker ("gambler") chooses one of n actions ("arms") in each time step.

Chosen arm produces random payoff from unknown distribution.

Goal: Maximize expected total payoff.



Where else do we see MAB applications?

- Crowdsourcing
  - assigning the right tasks to right users (Lin et al., 2022)
- Sequential clinical trials in medicine (Aziz et al., 2021)
  - finding the optimal dosage in early stage clinical trials
- Ad placement
  - allocating the budget of an advertiser across multiple surfaces optimally when both the demand and the value are unknown (Avadhanula et al., 2021)
- Price experimentation
  - deciding on real-time prices for a large number of products with incomplete demand information (Misra et al., 2019)
- Search
  - Fast and slow (Clarkson et al., 2020)
  - With multiple sensors (Song and Teneketzis, 2004)

An example

p_i: .3	p_i: .2	p_i: .2	p_i: .3
c_i: 6	c_i: 3	c_i: 10	c_i: 2
a_i: .9	a_i: .5	a_i: .6	a_i: .4

Search the location that maximises
$p_i * a_i (1 - a_i)^m / c_i$

Gittins Index from Multi-Armed Bandit

[0.045, 0.033, 0.012, **0.060**]

[**0.045**, 0.033, 0.012, 0.036]

$m=1$

A search policy is an ordered list of locations to search

4, 1, 4, 2, 4, 2, 4, 3, 2, …

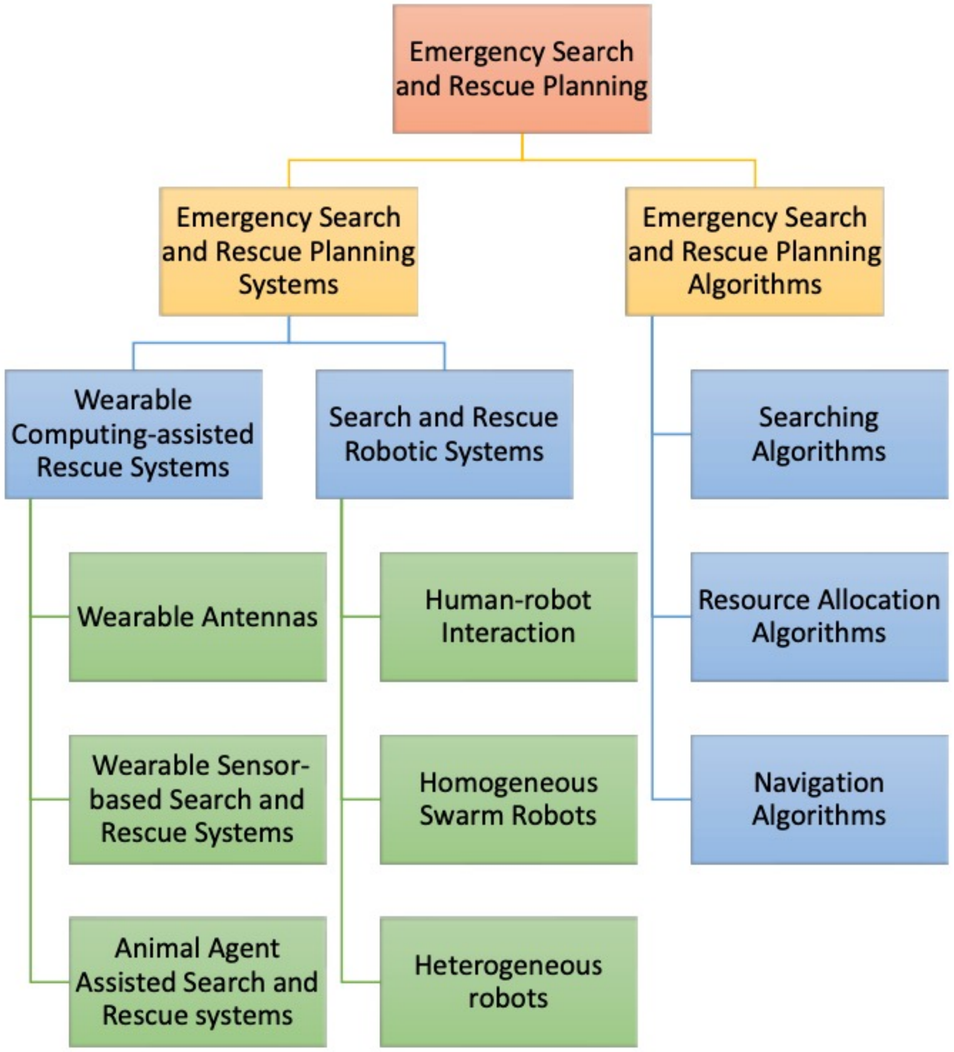
Find the policy that minimises the expected search time

Extensions

- Search and rescue missions: Find an object before a crucial deadline
  - Lost at sea: hypothermia
  - After an earthquake: survivors underneath collapsed buildings
  - A bomb squad: find a time bomb before it explodes
- In many cases, the crucial deadline is not known to the search team.

Lin and Singham (2016) propose a randomized search strategy that simultaneously maximizes the probability of finding the object by any deadline.

Concluding Thoughts



Bi & Glenbe, 2022

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