The Journal of Open Source Software

pyMassEvac: A Python package for simulating multi-domain mass evacuation scenarios

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DOI: 10.xxxxxx/draft

Software

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Editor: Open Journals

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Submitted: 01 January 1970
Published: unpublished

Summary

pyMassEvac is a Python package whose aim is to study mass evacuation scenarios. In particular, it is designed to simulate single- and multi-domain mass evacuation operations in which:

- the individuals to be evacuated are at a remote location, such as in the Arctic, where access to immediate medical care is limited or non-existent;
- each individual's medical condition may change over time, perhaps due to environmental conditions, injury, or care being provided; and
- the individuals must be transported from the evacuation site to a Forward Operating Location (FOL).

An example of a multi-domain mass evacuation operation, where the objective is to maximize the number of lives saved by transporting them to the FOL, that may be modelled using pyMassEvac is described in Rempel (2024) and is depicted in Figure 1.

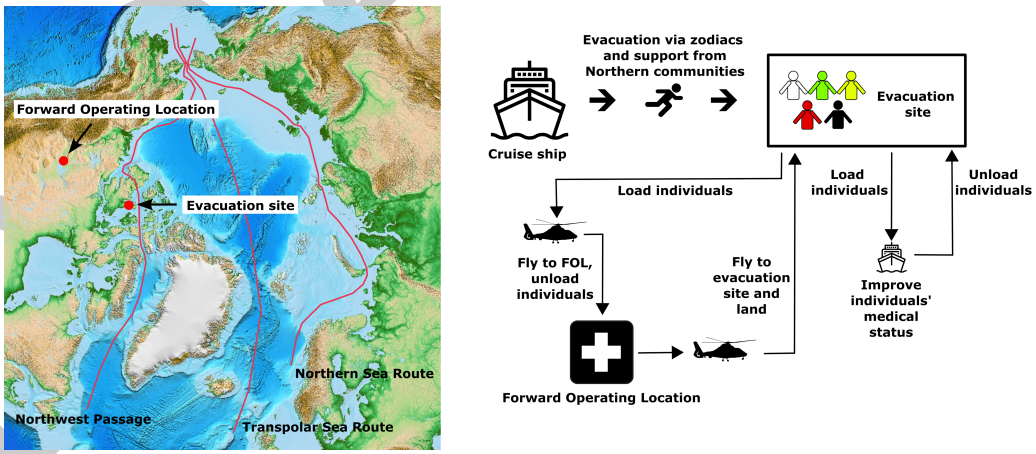

Figure 1: Evacuation plan via air with medical assistance provided at the evacuation site via ship. Colours of individuals at the evacuation site represent those in different triage categories.

Within this context, pyMassEvac may be used to provide decision support to defence and security planners in two ways. First, through exploring the impact of the policies to make the three decisions depicted in Figure 1 (see right panel):

- **Decision policy 1**: the policy that determines which individuals are loaded onto a vehicle, such as a helicopter, for transport to the FOL;
- **Decision policy 2**: the policy that determines which individuals receive medical care (if available) at the evacuation site, such as onboard a nearby ship; and

- **Decision policy 3**: the policy that determines which individuals are removed from the group receiving medical care, for reasons such as limited capacity or that the individuals' medical condition has been sufficiently improved, and returned to the group ready to be transported to the FOL.

Second, assuming decision policies are selected, decision support may be provided by using pyMassEvac to explore their robustness to the uncertainty in a scenario's parameters. For example, pyMassEvac may be used to explore how robust a set of decision policies is in terms of the number of lives saved with respect to:

- the arrival time of the initial transport vehicle after the individuals have arrived at the evacuation site;
- the distance, and thus travel time, between the evacuation site and the FOL; and
- the rate at which an individual's medical condition becomes better (through receiving medical care) or worse (due to injury or exposure to environmental conditions) over time.

In addition to uncertainty, changes in such parameters from baseline values may reflect a variety of real-world decisions beyond the scenario itself, such as:

- the reduction in the arrival time of the initial transport vehicle may reflect the pre-positioning of vehicles during the summer season;
- the reduction in the distance between the evacuation site and FOL may reflect the building a new aerodrome; and
- the decrease in the rate at which an individual's medical condition worsens may reflect the use of improved medical kit.

Thus, pyMassEvac is designed to be primarily used by operational researchers who study humanitarian or defence and security operations.

pyMassEvac is accessible at `https://github.com/mrempel/pyMassEvac` and is installed via a `setup.py` script. In addition, published evacuation scenarios that have studied using this package (or its earlier developmental versions) are described in Rempel et al. (2021), Rempel (2023), and Rempel (2024).

Statement of need

The significant decrease in Arctic sea ice in recent decades has resulted in increased activity in the Arctic across a range of sectors, such as oil and gas, mining, fishing, and tourism. As the ability to navigate the Arctic's primary sea routes—the Northwest passage, Northern Sea Route, and Transpolar Sea Route (see the left panel of **??**)— becomes more commonplace, their use for both trade and the transport of individuals will follow. In regard to the transport of individuals, for example via cruise ships, Arctic nations are concerned with both the potential increase in the number of Search and Rescue (SAR) incidents that may occur, and the increased size of those incidents in terms of the number of individuals in need of evacuation. This is evidenced by recent exercises that have been conducted, such as the SARex series in Norway Solberg et al. (2016); Solberg et al. (2018), a table-top exercise including the United States, Canada, and the cruise ship industry McNutt (2016), and NANOOK-TATIGIT 21 by the Canadian Armed Forces National Defence (2021).

- "mass evacuation" "software" - review what MassEvac can do and how does it not fit this need?
- reference Camur (2021)

While software exists to support planning for and executing evacuation operations, this software either requires a paid license, does not enable a researcher to study the impact of different decision policies, or ...

With this in mind, pyMassEvac aims to enable researchers to study the ...

Features

Mass evacuation operations are modelled in pyMassEvac as a sequential decision problem under uncertainty using Powell's universal framework for sequential decisions Powell (2022). Given this framework, a scenario's parameters are specified via the initial state variable S_0.

- m^e: Vector of mean time (hours) for an individual to transition from a triage category $t \in \mathcal{T}$ to the next triage category $t' \in \mathcal{T}$ at the evacuation site, i.e., m^e_w is the mean transition time from the white to green tag category. The set of triage categories is given as $\mathcal{T} = w, g, y, r, b$.
- m^s: Vector of mean time (hours) for an individual to transition from a triage category $t \in \mathcal{T}$ w to the next triage category $t' \in \mathcal{T}$ r while receiving medical care, i.e., m^s_r is the mean transition time from the red to yellow tag category.
- c^h: Total capacity for individuals onboard a helicopter.
- c_s: Total capacity for individuals to receive medical care.
- δ^h: Vector of capacity consumed by each triage category $t \in \mathcal{T}$ onboard a helicopter.
- δ^s: Vector of capacity consumed by each triage category $t \in \mathcal{T}$ when receiving medical care.
- η^h: Total time for a helicopter to load individuals at the evacuation site, transport them to the FOL, unload the individuals, and return to the evacuation site.
- η^{sl}: Total time to transfer individuals at the evacuation site to the local facility (such as a ship) in which they will receive medical care, plus the time until a decision is made as to which individuals to transfer back to the evacuation site.
- η^{su}: Total time to transfer individuals from the local facility (such as a ship) in which they are receiving medical care to the evacuation site, plus the time until a decision is made as to which individuals to transport to the FOL.
- τ^h: Arrival time of the initial transport vehicle after the individuals have arrived at the evacuation site.
- τ^s: Arrival time of the medical care facility (such as a ship) after the individuals have arrived at the evacuation site.

Limitations

Citations

Citations to entries in paper.bib should be in rMarkdown format.

If you want to cite a software repository URL (e.g. something on GitHub without a preferred citation) then you can do it with the example BibTeX entry below for (**?**).

For a quick reference, the following citation commands can be used: - `@author:2001` -> "Author et al. (2001)" - `[@author:2001]` -> "(Author et al., 2001)" - `[@author1:2001; @author2:2001]` -> "(Author1 et al., 2001; Author2 et al., 2002)"

Acknowledgements

I acknowledge contributions from Nicholi Shiell and Kaeden Tessier who are co-authors on related papers. These collaborations inspired the development of this package.

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