A Proactive Risk-Aware Robotic Sensor Network for Critical Infrastructure Protection

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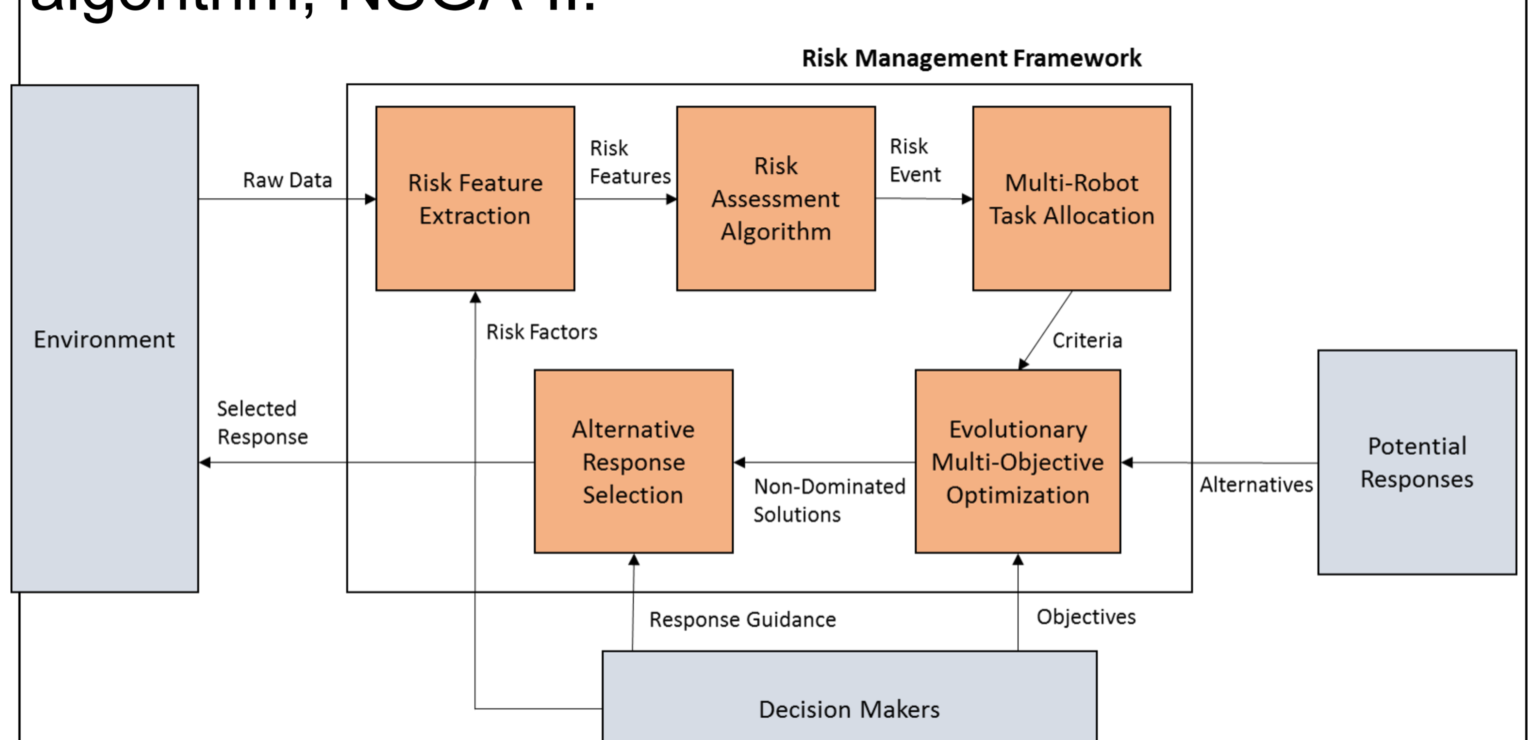
Introduction

Robotic Sensor Networks (RSN) can play a major role in the safeguarding of our Critical Infrastructures. “Disruptions of critical infrastructure could result in catastrophic loss of life, adverse economic effects, and significant harm to public confidence”[1]. Robots equipped with sensors can observe the environment and even assess the amount of risk in that environment. High risk in the RSN is undesirable and can represent a potential threat to the RSN resulting in a compromised security defense perimeter.

Risk Management Framework

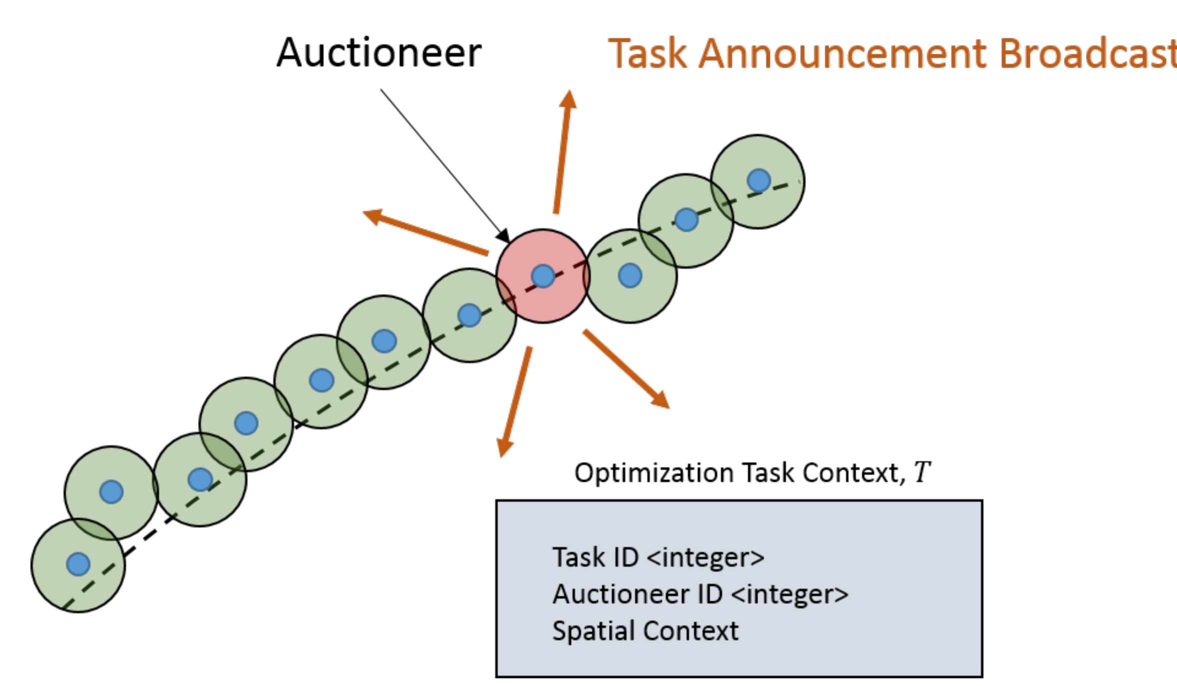
A Risk Management Framework (RMF) [2] has been developed and designed to be modular. Raw data is ingested and analyzed for risk to detect high-risk events. Robots are assembled into autonomous ground named coalitions through Multi-Robot Task Allocation (MRTA). Optimized robot topologies for the coalition are produced by the Evolutionary Multi-Obhective optimization algorithm, NSGA-II.



Block Diagram of the Risk Management Framework

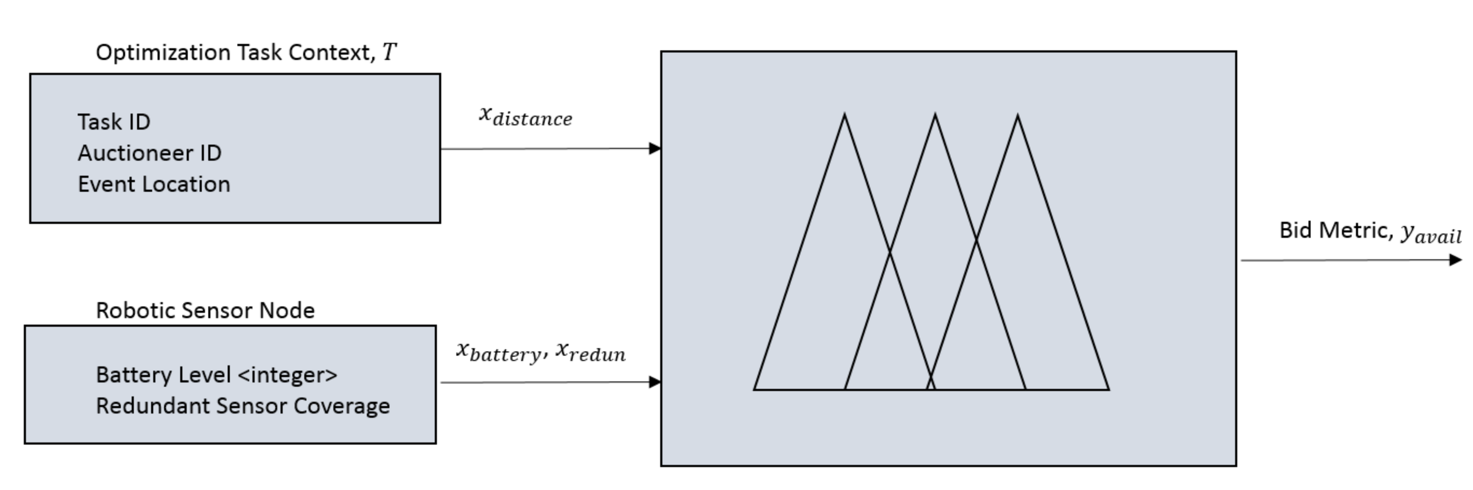
Fuzzy-Auction MRTA

A detected risk event in the RSN necessitates a response to mitigate the risk as much as possible. Upon processing a high-risk event a robot takes the leadership role of the ***auctioneer***. A task announcement message is sent.



Depiction of Task Announcement

A robot that is in the state *idle* can process a task announcement message and decide whether to place a bid. Bids are calculated using a Fuzzy Inference System. Bid metrics of 0.0 are not sent.



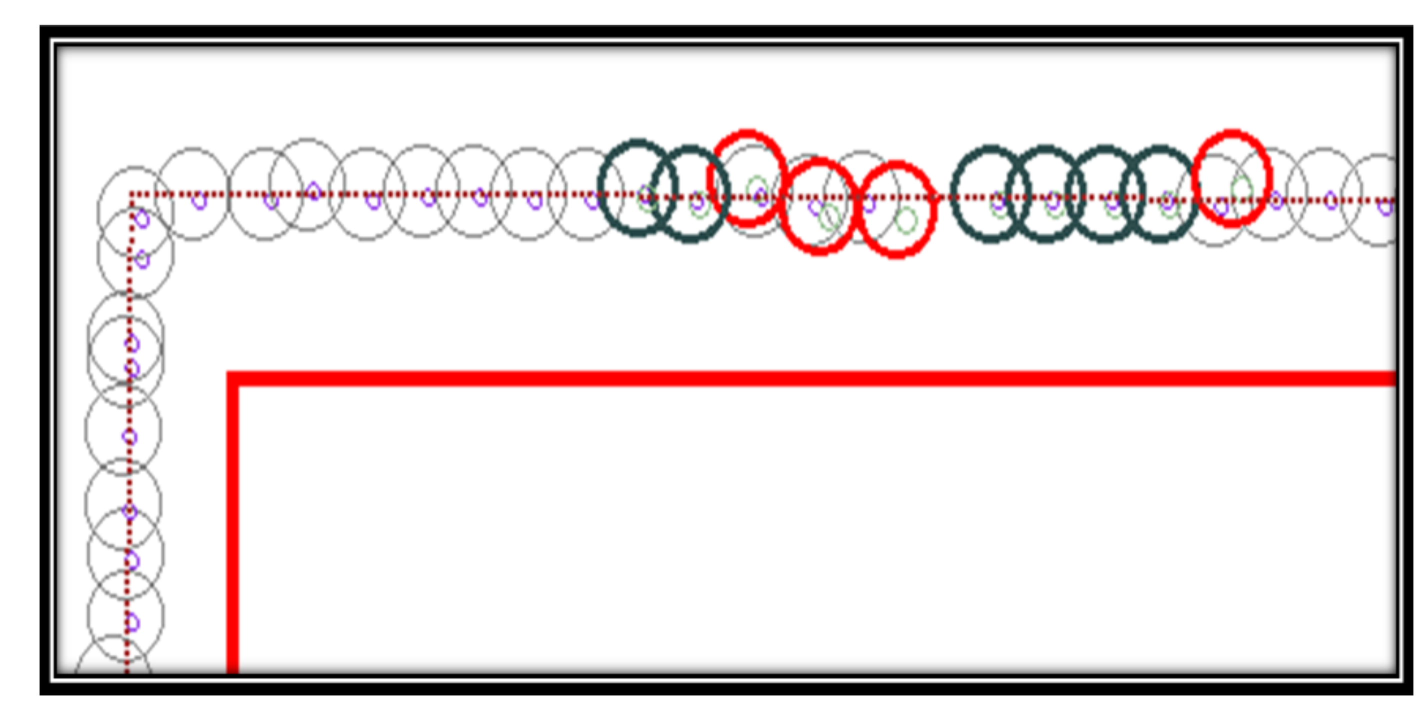
Fuzzy Bid Metric Calculation

The auctioneer awaits for bids to be placed. After ranking the bids based on highest value, the top bidders are notified. At this moment a robot coalition has been established.

Self-Organization

Given a coalition, the auctioneer hosts an optimization session using the NSGA-II. The optimization objectives are: **maximize coverage of secure perimeter** and **minimize movement energy**. The NSGA-II produces a set of Pareto optimal solutions

Experimentation



Network Response 0	Coverage: -0.994666695594788	Energy Cost: 2.04569816589355
Network Response 1	Coverage: -0.98933333158493	Energy Cost: 0.184831351041794
Network Response 2	Coverage: -0.993333339691162	Energy Cost: 1.19994390010834
Network Response 3	Coverage: -0.990666687488556	Energy Cost: 0.778060793876648
Network Response 4	Coverage: -0.991999983787537	Energy Cost: 0.954068839550018

References

[1] Canada. Public Safety Canada. “Action Plan for Critical Infrastructure”, 2009.
[2] R. Falcon, R. Abielmona and, A. Nayak: “An Evolving Risk Management Framework for Wireless Sensor Networks,” in 2011 Int'l Conference on Computational Intelligence for Measurement Systems and Applications (CIMSA), pp. 1-6, Sept 19-21, 2011.

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