Real Time Decisions for Resource Allocation in a Time Critical Dynamic Environment Based on Social Welfare and Local Search

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1 Introduction

- We consider an artificial intelligence approach to the problem of properly allocating the limited resource to victims in emergency care scenarios
  - An emergency or mass casualty incident (such as a highway traffic accident) occurred
  - Ambulances are allocated at site of the incident to drive victims to the hospital
  - Hospital allocation occurs once the patient arrives at the hospital
  - Our work addresses both determining the best allocation and supporting decision making (for medical staff to explore possible options)
    - We clarify how sensing can assist in updating the central system with up to date information
  - We identify this problem as a multiagent systems resource allocation
    - Our solution uses local search with social welfare functions in order to find the best allocations

2 Background

- Main approach: resource allocation using local search sensitive to social welfare function
- Multiagent resource allocation:
  - Intelligent agents representing patients
- Each has a severity for their injury, a resource that they need, and a waiting time
  - Severity 1 represents a patient in critical condition and Severity 4 represents patient in a good condition
  - Resources representing ambulances, hospitals, medical staff and equipment
    - Ambulances have a current location and a driver of a certain skill
    - Hospitals have a capacity (can be over capacity), distance from the incident, and the amount of resource available
    - Hospital resources include medical staff and equipment of a certain skill
  - When a patient is allocated a resource then it will be unavailable until the procedure is complete or it is allocated to another patient

3 Local Search

- There are many ways to allocate resources to patients
- Cost function allows comparisons of allocations
- Finding the best allocation has the lowest cost
- Starting with a possible initial allocation of resources to patients, local changes are made until it is no longer possible to improve on the allocations made
- Random restarts are used to improve the final allocations selected

4 Social Welfare

- These functions provide a global view of the scenario
- An allocation will produce a different value based on the social welfare function [1]

Utilitarian Social Welfare	$sw_u(P) = \sum_{i \in A} u_i(P)$
Egalitarian Social Welfare	$sw_e(P) = \min \{u_i(P) \mid i \in A\}$
Nash Product	$sw_n(P) = \prod_{i \in A} u_i(P)$

5 Overview

- The Ambulance scenario allocates to a victim an ambulance and a hospital
- The Hospital scenario allocates medical staff and equipment to a patient
- Both scenarios have an Allocation mode and a Decision Support mode
  - Allocation mode indicates the allocation that should be made at that situation
  - Decision Support mode allows a comparison of algorithms
- Policy
  - Principles of allocation (e.g. Lottery, FCFS, Youngest First, Sickest First, etc.) [2]
  - Social welfare function

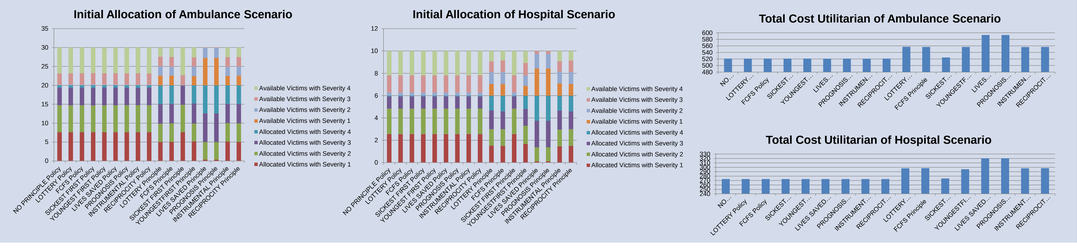
6 Algorithm

Input: current allocation, patients and resources available
Output: an allocation of resources to patients (optimal given the policy)
loop while *random restarts remaining > 0* **do**
  Initialize *Solution* as the current allocation with available resources allocated to available patients randomly;
  loop until *Solution* has no more neighbors **do**
    Set M to an unseen neighbor of *Solution;*
    if *policy in M < policy in Solution* then
      Solution = M;
    end
  end
  Add *Solution* to set of possible solutions;
end
return best *Solution* from set of possible solutions;

7 Validation

- We compared using the principles of allocation and the policy
  - 100 random restarts were used
  - 100 randomly generated runs for each scenario
    - Ambulance scenario: 30 victims, 20 ambulances, and 3 hospitals
    - Hospital scenario: 10 patients and 6 resources

8 Graphs



9 Conclusion

- These results are positive as the cost of using any of the policies had a lower cost than any of principles of allocation for both scenarios
- Emergency care scenarios are dynamic and it is important to keep track of the patients and resources
- Sensing provides the scenario with current information and ensures resources will continue to be allocated properly to the patients

10 References

- [1] Y. Chevaleyre, P. E. Dunne, U. Endriss, J. Lang, N. Maudet, J. A. Rodriguez-Aguilar "Issues in multiagent resource allocation." In Informatica 30, 2005.
- [2] G. Persad, A. Wertheimer, E. J. Emanuel. "Principles for allocation of scarce medical interventions" In The Lancet 373.9661 (2009): 423-431, 2009.