Large Scale Multi-Agent-Based Simulation using Exemplars

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ABSTRACT
Agent-based entity-level simulations have many decision support advantages that derive from straightforward mapping to the world [4]. A disadvantage of such an approach is that simulation runs are computationally expensive. The goal therefore is to reduce the total run time for the experiment by reducing the time it takes to complete a simulation, by having an efficient optimization that can find good results with fewer simulation runs and by distributed processing. This paper will discuss our investigations within the context of an Agent-Based Simulation (ABS) of the U.S. Navy Personnel Enterprise with hundreds of thousands of members. The focus will be on investigating the effectiveness and efficiency of exemplars in which the members of the exemplar groups follow a joint course of action. Dynamic creation and splitting of exemplars is required to accurately satisfy constraints such as budgets, quotas, and so on.

Categories and Subject Descriptors
I.6.3 [**Simulation and Modeling**]: Applications.

General Terms
Algorithms, Management, Performance, Design, Experimentation.

Keywords
Large-Scale, Agent, Modeling, Navy, Manpower, Distributed, Aggregation, Exemplar.

1. INTRODUCTION
Personnel planning in the U.S. Navy involves multiple functional areas such as recruitment, training, career management etc. with complex sub-goals that must be subordinate to the enterprise Navy goals. These functional areas are currently stove-piped due to incompatibilities of applications and data where success is measured locally, leading to management decisions without a full understanding of the enterprise-level impacts of those decisions.

The Comprehensive, Optimal Manpower and Personnel Analytic Support System[1] (COMPASS) optimizes personnel policy across all functional areas by simulating the decisions of sailors. The Navy will be able to utilize COMPASS to evaluate the implications of resource and policy alternatives across the entire enterprise, e.g., the impact of increasing or decreasing a budget on the readiness of the Navy.

The initial COMPASS prototype demonstrated multi-agent based simulation and optimization of approximately 6,000 sailors on a single processor. The current requirement is to enhance the system to scale up to about 80,000 sailor agents (with an ultimate goal of simulating the full 300,000+ enlisted member Navy), and to address the associated model fidelity and system performance tradeoff challenges.

2. ARCHITECTURE
Figure 1 illustrates the flow of information among the major components of COMPASS.

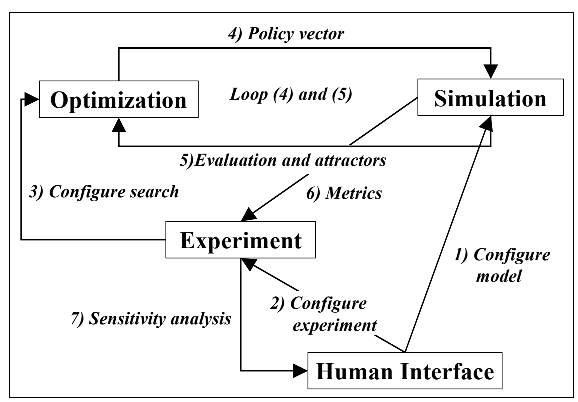

Figure 1. COMPASS component architecture.

[1] COMPASS was funded by the U.S. Navy Personnel Research Studies and Technology Division of the Navy Personnel Command. The views, opinions, and findings contained in this report are those of the authors only.

The Simulation component knows about personnel flows and policy: thus, how to apply a policy vector to an inventory state at time t to predict inventory state at time t+1. A policy vector is a set of policy parameter values such as Selective Reenlistment Bonus (SRB) budget, SRB Levels etc. The Optimization component strives to efficiently search the space of possible policy vectors to find robust solutions over a range of future environments that cover the interval from time t to t+1.

The optimizer exploits domain-specific insight created by simulation runs–in the form of suggestions from Function Agents [2]–to significantly reduce the required number of simulation runs. The Experiment component uses best-first search to combine policy vectors to cover the planning horizon from time t to t+n.

3. SIMULATION

Within a simulation, Function Agents, which have a global perspective, monitor sailor decisions and enforce policy constraints represented by the elements of the policy vector. Sailor Agents navigate through decision trees that embody the Navy Personnel Enterprise logic from the sailor perspective. For example, as sailor agents approach a reenlistment decision and the SRB budget approaches exhaustion, the Function Agents coordinate the sailor agents by posting information to a blackboard (causing rate model estimates of the probability of reenlistment to diminish). This behavior reflects realistic execution of Navy policy, where managers use a variety of techniques to influence sailors. Once the budget is exhausted, sailors are precluded from reenlisting.

4. EXEMPLARS

Here we propose to investigate grouping N sailors together and then running this packet, or exemplar, through the simulation as though they were one sailor in order to achieve significant speed up. The similarity measure used in the clustering process depends on a number of classifiers. These are the sailors' attributes that are predominant in the decision making at various nodes in the decision trees. Some candidate attributes are skill, pay grade and length of service (LOS) (see Figure 2). In addition to these attributes, an exemplar also has a parameterized size attribute. For example, the parameter might be 1:100, meaning the system would run an entity through the simulation in which the entity represents an exemplar of 100 sailors. To avoid problems with a fixed packet size larger than the small-sized skills, dynamic size determination using clustering and/or size-proportional grouping (such that each exemplar represents a specific proportion of a skill size, e.g., 1/100) will be investigated. Besides classical data clustering techniques [1], a self-organizing, swarming approach designed for dynamic environments may be investigated [3].

An interesting complexity is that an exemplar may need to be decomposed into two sub-exemplars with different states during a decision. For example, if a 100-sailor exemplar group reenlists then the SRB budget is reduced by an amount equivalent to giving an SRB to 100 sailors. Should there not be enough budget left to give an SRB to all 100 sailors, then the system will dynamically split the exemplars to separately complete the decision trees.

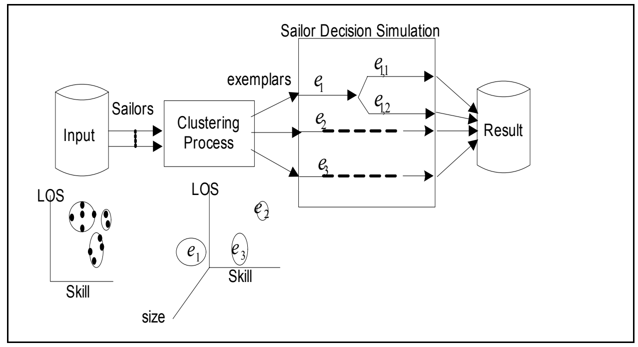

Figure 2. Generating and splitting exemplars.

The research may extend to experimenting with various statistical approaches to "reconstitute" the pseudo inventory to the entity level. The effectiveness and efficiency of achieving the goal will be measured by comparing the model fidelity and system performance at various levels of exemplar clustering vs. the individual entity level.

5. CONCLUSION

The initial COMPASS system demonstrated the feasibility of ABS optimization for large, stove-piped organizations such as the Navy Personnel Enterprise. Exemplars, representing groups of members following joint course of action, provide a promising approach to mitigate the computational cost of simulating large numbers of entity-level agents as we scale up the system.

6. REFERENCES

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