# Minerva-DCA: An Intelligent Agent for Ship Damage Control

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**Abstract**

The decision making task of ship damage control includes addressing problems such as fire spread, floods, smoke, equipment failures, and personnel casualties. It is a challenging and highly stressful domain with a limited provision for real-life training. In response to this need, a multimedia interactive damage control simulator system, called DC-Train 2.0 was recently deployed at a Navy officer training school; it provides officers with an immersive environment for damage control training. This paper describes a component of the DC-Train 2.0 system that provides feedback to the user, called the automated instructor assistant. This assistant is based on a blackboard-based expert system called Minerva-DCA, which is capable of solving damage control scenarios at the "expert" level. Its innovative blackboard architecture facilitates various forms of user assistance, including interactive explanation, advising, and critiquing. In a large exercise involving 500 ship crises scenarios, Minerva-DCA showed a 76% improvement over Navy officers by saving 89 more ships.

## 1. THE DOMAIN OF SHIP DAMAGE CONTROL

The tasks of ship damage control are vital to ship survivability, human life, and operational readiness. Most crises on military and civilian ships could be successfully addressed if handled promptly and properly. Typically the crisis management efforts on a ship are directed by a single person called the Damage Control Assistant (DCA). This person is in charge of maintaining situational awareness, coordinating crisis management crews, and managing other resources. Naturally, crisis management tasks are challenging even for seasoned Navy officers due to the inherent complexity of physical damage, limited resources, information overload, uncertainty, infrequent opportunities for realistic practice, and psychological stress. Studies have shown that the performance could be significantly improved by providing more opportunities for realistic practice [5, 1]. As in many other military domains, real-life training in often infeasible or inadequate due to the high cost and a limited number of possible scenarios. A complement to textbook training is computer simulations [5]. One such damage control simulator, the DC-Train 2.0, is capable of modeling a wide range of realistic scenarios [2].

However, a computer simulation trainer still needs a human instructor to (1) demonstrate a successful scenario solution, (2) provide the novice with instructional advice, (3) observe the novice's problem-solving and provide a comprehensive critique, and (4) score performance on various scenarios for progress evaluation and comparative analysis purposes. While DCTrain 2.0 is implemented with numerical and knowledge-based simulation techniques, requirements of an automated instructor include (1) an achievement of the level of expertise sufficient to solve arbitrary scenarios in real-time; (2) an ability to observe the novice in real-time, communicate with the novice, and present intelligible feedback in a natural language format. Such functions clearly present an interesting challenge for modern artificial intelligence technology.

## 2. DESIGN

Minerva-DCA is a real-time problem-solver, capable of explanation, advising, critiquing, and scoring, thus serving as an automated instructor for the damage control environment. These abilities result from utilizing the following innovative combination of AI technology:

1) **Exhaustive Probabilistic Deliberation:** Minerva-DCA is based on a blackboard architecture [3,2] with a deliberation step that produces a probabilistic rating for a wide range of possible next actions. These ratings provide a basis for identifying and differential critiquing of sub-optimal user actions.

2) **Envisionment Based Scheduling:** An Extended Petri Net envisionment system simulates the future to determine the quality of each deliberated action. The simulation shows the effect of each of each deliberated action on the course of the ship crises. When a users action is not in the set of the deliberated actions, this "creative" action can be evaluated using envisionment to determine its impact on crisis management.

3) **Dynamic Strategy Networks:** a unification of the domain-level and strategy-level rules produces strategy networks in real time. These relate high-level damage control goals to the domain actions. These strategy networks facilitate explanation, advising, and critiquing [2].

## 3. MINERVA-DCA EXPERIMENTAL EVALUATION

To evaluate the performance we have run over 500 scenarios of the DC-Train ship damage control simulator at the Navy officer training school in Newport, R.I. [2]. We have compared the problem-solving performance of Minerva-DCA to Navy officers. Minerva-DCA has shown a 46% improvement over Navy officers in the number of ships being lost (21 vs. 39) and a 76% improvement in the number of ships being saved (117 vs. 28).

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## 5. REFERENCES

1. Baumann, M.R.; Sniezek, J.A.; Donovan, M.A.; Wilkins, D.C. 1996. Training effectiveness of an immersive multimedia trainer for acute stress domains: Ship damage control. Technical report UIUC-BI-KBS-96008. Beckman Institute, University of Illinois.

2. Bulitko, V. 1998a. Minerva-5: A Multifunctional Dynamic Expert System. MS Thesis. Department of Computer Science, University of Illinois at Urbana-Champaign.

3. Carver, N.; Lesser, V. 1994. The Evolution of Blackboard Control Architectures. In Expert Systems with Applications – Special Issue on the Blackboard Paradigm and Its Application, Volume 7, Number 1, pp. 1-30, Liebowitz. New York, Pergamon Press.

4. Ericsson, K.A.; Krampe, R.T.; Tesch-Romer, C. 1993. The Role of Deliberate Practice in the Acquisition of Expert Performance. Psychological Review, 100(3): 363-407.

5. Jones, R.M.; Laird, J.E.; Nielsen, P.E. 1998. Automated Intelligent Pilots for Combat Flight Simulation. In Proceedings of The Tenth IAAI conference. AAAI Press. pp. 1047-1054.