# Hybrid Neural Network and Fuzzy Logic Approaches for Rendezvous and Capture in Space

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## 1 Background

The non-linear behavior of many practical systems and unavailability of quantitative data regarding the input-output relations makes the analytical modeling of these systems very difficult. On the other hand, approximate reasoning-based controllers which do not require analytical models have demonstrated a number of successful applications such as the subway system in the city of Sendai [5]. These applications have mainly concentrated on emulating the performance of a skilled human operator in the form of linguistic rules. However, the process of learning and tuning the control rules to achieve the desired performance remains a difficult task.

Fuzzy Logic Control is based on fuzzy set theory [6]. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or no membership at all, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a set.

## 2 Rendezvous and Capture

The Space Exploration Initiative mission architectures outlined in the Synthesis Group Report (Stafford report) call for the development of autonomous rendezvous and docking techniques as a critical technology. The National launch System program is sponsoring a workshop to investigate the technology readiness level of the technology in support of the cargo transfer vehicle element of the National Launch System.

To date the US has no experience whatsoever in this field although extensive research has been carried out. The Soviets have been employing AR&D since 1967 with their unmanned Progress tankers that resupply the Mir space station with consumables. Autonomous is

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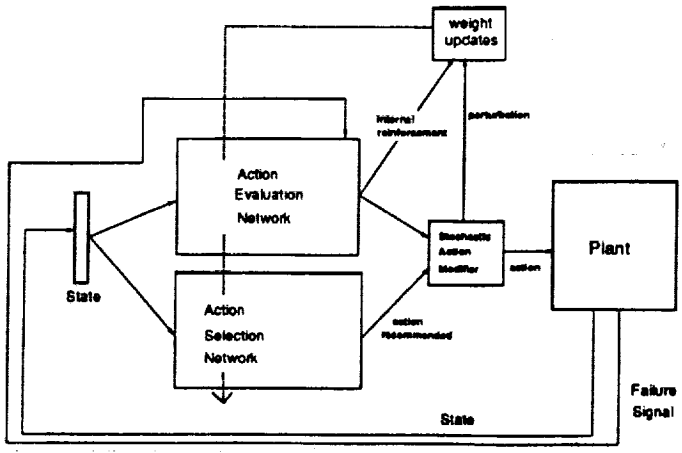


Figure 1: The Architecture of GARIC.

defined in this context as closed loop control onboard one of the two vehicles (target or chaser) without ground intervention or onboard operator control.

# 3 Approach

A true systems approach will be undertaken to explore and expand AR&D mission requirements based on program high level goals. A study of Soviet practical flight experience and US research efforts will be undertaken to set a framework for the requirements analysis and system level trade studies.

Once conventional techniques are understood, an evaluation will be made of advanced artificial intelligence techniques such as GARIC (Generalized Approximate Reasoning-based Intelligent Control) architecture [3] which has been developed at Ames for potential application in this domain. GARIC determines a control action by using a neural network which implements fuzzy logic inference. In this way, prior expert knowledge can be easily incorporated. This knowledge is allowed to be faulty or damaged. Another neural net will learn to become a good evaluator of the current state and will serve as an internal critic. Both networks will adapt their weights concurrently so as to improve performance. The architecture of GARIC is schematically shown in Figure 1. It has three components:

- The Action Selection Network maps a state vector into a recommended action, using fuzzy inference.
- The Action Evaluation Network maps a state vector and a failure signal into a scalar score which indicates state goodness. This is also used to produce internal reinforcement.
- The Stochastic Action Modifier uses both the selected action and the internal reinforcement to produce an action which is applied to the plant.

Our recent experience [1] in applying a hybrid neural network and fuzzy logic control architecture [2] to a fuzzy logic controller developed at Johnson Space Center (JSC) for attitude control of the space shuttle [4], will assist us in evaluating GARIC for rendezvous and capture.

Advanced techniques have the potential for providing a more robust operational system that may safely dock in the presence of hardware faults or unanticipated conditions. The relative merits of these systems will be evaluated. The impact of the chosen technique on the entire vehicle system will be evaluated including hardware, operations, mass, power, communication, tracking,consumable expenditures etc.

Collaborations with scientists and engineers throughout the Information Sciences, Human Factors and Fight Systems and Simulation Division of the Aerospace Systems Directorate of NASA Ames Research Center is anticipated because of the tremendous in house expertise of these organizations.

**Long term Goals** A software simulation and or hardware docking simulation that allows the evaluation of various techniques will be developed based on tools used by the flight dynamics organization at JSC.

## References


[1] H. Berenji, Y. Jani, and R. Lea. Approximate reasoning-based learning and control for proximity operations and docking in space. In *AIAA Guidance, Navigation and Control Conference*, New Orleans, Louisiana, August 12-14, 1991.

[2] H.R. Berenji. An architecture for designing fuzzy controllers using neural networks. *International Journal of Approximate Reasoning*, 1991 (in press).

[3] H.R. Berenji and P. Khedkar. Learning and tuning fuzzy logic controllers through reinforcements. *(Under review for journal publication)*, 1991.

[4] R. Lea, J. Hoblit, and Y. Jani. Performance comparison of a fuzzy logic based attitude controller with the shuttle on-orbit digital auto pilot. In *North American Fuzzy Information Processing Society*, Columbia, Missouri, May 1991.

[5] S. Yasunobu and S. Miyamoto. Automatic train operation by predictive fuzzy control. In M. Sugeno, editor, *Industrial Applications of Fuzzy Control*, pages 1–18. North-Holland, Amsterdam, 1985.

[6] L. A. Zadeh. Fuzzy sets. *Information and Control*, 8:338–353, 1965.