

KNOPS: AN EXPERIMENTAL KNOWLEDGE BASED TACTICAL AIR MISSION PLANNING SYSTEM
AND
A RULE BASED AIRCRAFT IDENTIFICATION SIMULATION FACILITY

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KNOPS (from Knowledge Based System), proper, refers to an experimental system under development at the MITRE Corporation to explore the applicability of artificial intelligence techniques to the implementation of an automated, extremely flexible tactical mission planning consultant. This paper will discuss that system and then another which supports the rule based simulation of aircraft identification strategies.

1. MISSION PLANNING:

Tactical mission planning may be posed as the intelligent utilization of one's available tactical air resources. Projections of possible theater level tactical conflicts indicate an expectation of very intense, complex, and time sensitive planning requirements as well as a requirement to improvise and implement novel tactical doctrine in response to unforeseen modes of weapon systems employment by the enemy. It is our thesis that knowledge based techniques represent the most promising approach towards the achievement of such trainable software. Work has concentrated on the problem of planning interdiction attacks, particularly in the choice of attack aircraft, munitions, and the electronic protection required to gain those aircraft safe passage. Currently the system is undergoing intense detailed design, while parts have been implemented in INTERLISP. These latter are sufficient to serve frequent "advocacy" demonstrations of the flexibility, human legibility and system self-explanation capabilities associated with knowledge based systems.

1.1 DATA BASE: There are basically two data bases; one for resources, the other for targets. Targets are to be stored in a hierarchical data base represented as list

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structure in the INTERLISP virtual storage. Individual targets are to be stored as FRL [3] frames. At this writing, we are involved in the translation of FRL from MACLISP into INTERLISP. The individual target frames are in fact depositories of simple record type information, with the procedures to be invoked when such values are needed or changed being derived by inheritance chains through more generic "target class" frames.

1.2 KNOWLEDGE REPRESENTATIONS: The system will employ two forms of knowledge representation; production rules and frames. The rules are chained backwards in a deductive manner to manage such generic choices as aircraft, weapons, support, and electronic counter measures. Software has been implemented for the interpretation, the translation (in both directions) between the internal form of the rules and the user legible/writable form, the explanation of deductions (in terms of the entire chain of rules and data employed in a deduction), and the creation and editing of rules.

A typical (MYCIN-like) rule for the selection of munitions is:

--TR17--

IF:

- 1: THE target IS PINPOINT
- AND 2: THE CLOUD COVER OF THE target
IS LESS THAN 2/8
- AND 3: THE time on target IS WITHIN DAYTIME
- AND 4: THE AAA DEFENSE OF THE target
IS MORE THAN LIGHT
- AND 5: PAVE KNIFE IS AVAILABLE AT time on target

THEN:

- 1: THE BEST MUNITIONS FOR THE target IS
ONE OF: MK-82-LG, MK-83-LG, MK-84-LG

Lower case indicates variables. The justification for this rule can be inferred from the discussion in [2], p. 782.

The syntactic pattern matcher employed by the inference mechanism is quite general. It includes synonym and spelling correction capabilities, as well as provision for restrictions on variable instantiations defined by arbitrary multivariate predicates. This matcher is also employed to implement a flexible command-query system.

Frames will be employed to represent both the data base and, at a higher level, missions and support sub-missions. Frames are particularly attractive with respect to the time sharing of support missions, (e.g., reconnaissance, refueling, and SAM suppression) among several attack missions.

1.3 EXAMPLE: The following dialog (user lines start with "&&") is possible in the current system:

```
&& WHAT IS THE HARDNESS OF TARGET 2?
THE HARDNESS OF TARGET 2 IS UNKNOWN
&& HOW ABOUT TARGET 1?
TARGET 1 IS VERY HARD
&& WHY?
BY TR3: TARGET 1 IS VERY HARD
  SINCE:
    1: DATA: TARGET 1 IS A BRIDGE
&& IS TARGET 3 AN AIRBASE?
NO, TARGET 3 IS AN SA-4
&& CHOOSE MUNITIONS FOR IT
THE BEST MUNITIONS FOR TARGET 3 IS SHRIKE
&& WHY?
BY MR4: THE BEST MUNITIONS FOR TARGET 3 IS SHRIKE
  SINCE:
    1: BY TR1: TARGET 3 IS AN EMITTER
      SINCE:
        1: BY TR4: TARGET 3 IS A SAM
          SINCE:
            1: DATA: TARGET 3 IS AN SA-4
```

For more information about SA-4's, SHRIKES and why one is bad for the other, see [2] pp. 77 and 150.

2. AIRCRAFT IDENTIFICATION:

A critical contemporary military need is for a method of sure, safe identification of aircraft, capable of reliable distinction between friend and foe (IFF). We shall concentrate here on approaches to the IFF

problem based primarily on "cooperative" techniques. It seems possible today to build electronic query and response systems that almost solve the problem electronically. Difficulties, though, stem from the facts that in certain theaters it is anticipated that an aircraft would be required to pass thousands of such query-response tests -- and pass all of them to survive, that equipment can fail completely, that a spread spectrum signal might be detected if it happens to be near enough to and in the direction of an enemy receiver which is afforded sufficient integration time, and that jamming is in fact quite often possible. In addition, tomorrow's war must be as silent as possible, for in querying an aircraft for identification, the inquirer exposes both himself and the plane, should he be a friend. Therefore one should not normally query without the intent to fire. It seems likely that the query should also transmit (crypto-securely) information such as the position and the weapon the inquirer is contemplating firing. The aircraft may then use that information to decide whether or not to respond on the basis of all the threats he has perceived or inferred. The logic of the IFF problem thus becomes one of evaluating procedural strategies in a collusive, n-person game. Such evaluation is proving error-prone as more complex IFF "solutions" are being proposed and more thorough analyses demanded.

2.1 WHAT SHOULD BE DONE: Our first response was to initiate the design of a rather general knowledge based IFF game definition and execution system. In fact, there are a number of "electronic warfare" problems that share this same "gaming" characteristic: electronic counter and counter-counter measures, the exploitation or defeat of the enemy's surveillance or intelligence structure, the maintenance of survivable communications and/or surveillance networks, or the penetration by an interdiction aircraft of the enemy's defenses. For a knowledge based approach to this last, see [1]. While we are stressing the IFF problem in this paper, it was our intent that the game definition/execution mechanism be sufficiently general to support study of the logic of many of these "electromagnetic warfare" problems.

2.2 WHAT WE HAVE DONE: KNOBS has been augmented by the addition of a forward chaining production system in which the conflict set resolution algorithm chooses the minimal set of rules that covers the maximal set of facts (as discussed in [4]). This has been employed to create a simulation of the world as it might be

seen by a single "Blue" surface-to-air missile (SAM) site. The SAM has a number of choices to make: whether to turn its radar on or off, whether or not to query each plane it has detected, and whether or not to fire at such a plane. Our initial thought was to model the SAM's strategies for these choices by a set of productions. What we have done, in fact, is to write a number of production sets, basically one for each iterative step in the game, and to use the production system interpreter as the mechanism for the entire simulation. This rather simple idea turns out to be quite powerful. The resulting simulations, in which not just the strategies but also the weapons systems limitations and even the "physics" are represented by human legible rules, yield a strong sense of cause and effect between hypothesized principles of behavior and game results.

2.3 SAMPLE RULE: The following is a quite conservative rule meant to express a determination not to query an aircraft unless it is perceived as a possible direct threat to the SAM:

```
IF:                                --QUERY1--
    1:  RADAR IS ON
    AND 2:  SAM HAS MISSILES LEFT
    AND 3:  ?A/C HAS NOT BEEN FIGURED
    AND 4:  ?A/C HAS NOT BEEN QUERIED
    AND 5:  ?A/C IS LOW
    AND 6:  ?A/C IS FLYING WEST
THEN:
    1:  QUERY ?A/C
```

Identifiers starting with "?" represent existentially quantified variables.

2.4 SAMPLE RUN: The listing below is an excerpt from an actual game run. We have preserved just enough to trace the dissimilar fates of two planes, P0004, a Blue F-111F, and P0008, a Red MIG-21, with rather similar histories:

```
STARTING TURN # 1
...
AIRCRAFT P0004 OF TYPE F-111F HAS ENTERED RANGE
...
AIRCRAFT P0008 OF TYPE MIG-21 HAS ENTERED RANGE
SAM QUERIES P0004
FIGURE P0004 IS RED
S1 FIRED AT P0004
...
SAM QUERIES P0008
FIGURE P0008 IS RED
S3 FIRED AT P0008
```

```
...
STARTING TURN #2
...
STARTING TURN #3
...
MISSILE S1 MISSED
...
MISSILE S3 MISSED
...
S5 FIRED AT P0008
...
STARTING TURN #4
P0004 --A F-111F -- PASSED THROUGH SAFELY
...
STARTING TURN # 5
...
MISSILE S5 HIT
P0008 -- A MIG-21 -- DESTROYED
```

By reference to the rules and some descriptive data, it is very easy to understand what happened. Both planes aroused the SAM's suspicion since they were flying WEST and LOW. Both therefore got queried. Neither responded: the MIG because it was Red and therefore did not know the code key and the F-111 because its IFF equipment was broken. Both therefore were figured Red and were fired upon. Both were saved from this round of missiles by their ECM. P0004 then passed out of range. Unfortunately for P0008, it stayed in range long enough to allow the SAM time for a second shot. This time the ECM was inadequate and the A/C was destroyed.

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