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The Director of Central Intelligence

Washington, D.C. 20505

Intelligence Research & Development Council

ARTIFICIAL INTELLIGENCE STEERING GROUP TRIP REPORT

DATE/PLACE

10 May 1984
MITRE Corporation
McLean, Virginia

ATTENDEES

AISG

[redacted]

MITRE

[redacted]

STAT

DETAILS

In lieu of our May meeting, the AI Steering Group visited the Washington C^3I Operations of MITRE Corporation in McLean, Virginia. The all-day session consisted of presentations, demonstrations, and discussions of several MITRE AI projects of potential interest to the Intelligence Community. The visit was hosted by Mr. George Steeg, Chief Engineer of MITRE's C^3I Operations activity. An agenda is attached.

The first speaker, [redacted] described and demonstrated STAT the ANALYST system, a prototype expert system for intelligence fusion and situation assessment. The ANALYST system employs three

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levels of reasoning involving Tactical Intelligence Reports, Order of Battle Information, and Analysis of Critical Indicators. It uses (incomplete) information from COMINT, ELINT, and IMINT in a common report format. The system operates with the Battlefield Environment Model, an object-oriented simulation (written in ROSS on the VAX) in which all units act according to some pre-established doctrine.

MITRE has invested 10 staff-years in developing the ANALYST system, and so far it has 120 "rules." [redacted] estimated that an operating version might grow to 1500 rules which would require moving the system from a VAX to a 2MB Lisp Machine. The system has a menu-oriented user interface and can ask the user to supply data and confidence factors. The mathematics of how to combine confidence factors most effectively is still under consideration. There is a rule editor to facilitate adding or changing rules and an explanation capability to explain how the system arrived at an answer. A set of viewgraphs is attached. More detail is available from MITRE in a report on ANALYST: MTP-83W00002, February 1984. STAT

[redacted]s talk addressed the subject of Military Planning. Planning systems generally are characterized by: STAT

- A hierarchy of plans
- Deferred time ordering
- Introspection and modification of plans
- Deferred introduction of constraints.

Military planning (and to a large extent business planning) is characterized by:

- No "right" plan
- Not able to choose the "best" plan
- Unknown constraints and data
- Erroneous constraints and data
- "Commander's prerogative."

MITRE has developed a system for logistics planning, but it, like most automated planning efforts, suffers the following deficiencies:

- Cannot produce partial plans
- Difficult to trace the results of following a plan
- Untimely response
- Hard to check plans
- Not able to develop concurrent plans
- Difficult to modify plans or monitor their execution.

MITRE has an IRAD project underway to address these deficiencies using an AI approach. They are using a joint military operation scenario which has been supplied by the Armed Forces Staff College.

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Dr. Benoit suggested that there may be intelligence applications of this planning approach in the area of indications and warning (either to detect deviations from an expected scenario or to fit a behavioral model to the observed data).

[redacted] discussed human factors in conjunction with the design of expert systems. While acknowledging the importance of human factors issues in designing the end-user interface, Dr. Stech focused his talk on the process of knowledge acquisition and the need to systematically question knowledge before it goes into a system. Several methods and tools were described and [redacted] emphasized a process called "chunking" of knowledge. Experiments have verified that chess masters "chunk" situation reports about a chess board status that enables them to reproduce a game board rapidly and accurately. MITRE is investigating how tactical analysts perceive a situation map and is setting up an analogous set of experiments to determine the key features of a map that an expert focuses on. A set of viewgraphs is attached. STAT STAT

[redacted] next discussed the subject of photo interpretation and demonstrated a PI softcopy workstation environment. The particular application task demonstrated was the recognition of significant changes of man-made objects in images of the same location taken at different times. The goal of this project is to develop a laboratory and a set of tools (as opposed to building a complete system) which can be used to experiment with developing <u>aids</u> for image analysts (not full automation). Future work will involve adding 3-D models, using shadow information, applying it to urban areas, and studying the use of specialized image processing hardware. A set of viewgraphs is attached. STAT

MITRE also has AI work going on at their Bedford, Massachusetts, operation, and [redacted] described four AI projects at MITRE/BEDFORD. The KNOBS project (which the AISG saw demonstrated at Symbolics in Cambridge last Fall) provides assistance in tactical air mission planning. The KNOBS approach employs natural language processing, rules, frames, and templates. The general architecture has been reapplied to several other planning areas for NASA and the Navy. MITRE has also been working in the field of Natural Language (question-answering, inferencing, and command interpretation). Their current interests are moving toward multiple ways of presenting answers using natural language and graphics. Their Knowledge-Based Automatic Programming project employs an application knowledge base to facilitate rapid prototyping and debugging of a system. This project is similar to RADC's work in this area but is, perhaps, broader in scope. Next, [redacted] described an Expert System they are building for NASA to support mission GO/NOGO decisions by analyzing and validating sensor indications which monitor the liquid oxygen supply. Finally, he talked about their STAT STAT

Future Generation Computer Architecture project. This work involves Multiple Instruction/Multiple Datastream machines and a "smart" memory interconnect scheme to link multiple processors (up to, perhaps, 1 million).

[redacted] summarized several general research issues which the Bedford projects are attempting to address. STAT

- Developing a KNOBS Replanning System
    - Resource allocation
    - Monitoring missions
    - Achieving interaction among missions
- Disambiguating natural language text and maintaining a conversational context
- Achieving incremental program specifications changes, removing temporary inconsistencies, and deciding which rule to apply
- Controlling mechanized reasoning for efficiency and for naturalness
- Permitting continuous replanning
- Monitoring the results of a plan.

The last speaker was [redacted] who presented a prototype expert system for resolving aircraft conflicts (a project for the Federal Aviation Administration). The system, which was demonstrated, uses information which predicts violations of safe separation policies up to 30 minutes in advance. Twenty-seven expert rules are then applied to determine for the air traffic controller suggested strategies for resolving the forthcoming conflict (e.g., plane A ascend and plane B turn right). The rules embody a set of doctrinal constraints about such things as right-of-way, restricted air space, and general aviation principles. A set of viewgraphs is attached. STAT

[redacted] STAT

Executive Secretary
AI Steering Group

AI Briefing

10 May 1984

CAMIS Briefing Room

Wilson Building

MITRE C^3I/Washington

[redacted] 9:00 STAT

Expert Systems for Intelligence Fusion and Situation Assessment

The battlefield environment is used as a model to develop expert systems to fuse and assess the dynamic information available. Adaptation to the changing environment and automatic correction of rules are being investigated. A demonstration will be presented.

[redacted] 10:30 STAT

Artificial Intelligence Applied to Military Planning

A demonstration Expert System has been developed which applies rules to the logistic planning of crisis responses. Operating bases and transportation facilities may be selected in this system. A more powerful system is under development and will be discussed.

[redacted] 11:30 STAT

Human Factors Design of Expert Systems

The objective of this research is to develop a methodology to assess the strength and weaknesses of human experts and to use this information in the design of expert systems. A secondary objective of this research is to develop methods to test the value added by the system, (i.e., the degree to which the expert system does, in fact, compensate or correct the weaknesses of human experts and reinforce their strengths).

Lunch 12:00

[redacted] 1:00 STAT

An Overview of MITRE-Bedford AI Work

The efforts discussed will include tactical planning, natural language understanding and automatic programming.

[redacted] 2:00 STAT

AIRPAC - Advisor For Intelligent Resolution
of Predicted Aircraft Conflicts

An Expert System uses heuristic rules to develop and evaluate a list of feasible actions to avoid aircraft conflicts. These proposed solutions are presented to the air traffic controller for selection. A demonstration will be presented.

[redacted] 3:00 STAT

Computer Vision as a Photographic Intelligence Aid

This talk will briefly describe MITRE's current effort to adapt Computer Vision technology to aid the photo-interpreter, in a softcopy workstation environment, to identify the first signs of man-induced change of potential significance.

AN EXPERT SYSTEM FOR RESOLUTION OF AIRCRAFT CONFLICTS
COMPUTER DEMONSTRATION

MITRE/METREK
IR&D 95690
PROJECT TEAM:
CURTIS SHIVELY
KARL SCHWAMB
JILL NICOLA

WHY CONSIDER KBS TECHNIQUES FOR ATC?

- O ATC REQUIRES COMPLEX DECISIONS, CURRENTLY PERFORMED BY HUMAN EXPERTS
- O LIMITATIONS OF ALGORITHM-BASED COMPUTERIZED DECISION AIDS
  - DIFFICULTY ESTABLISHING RELATIONSHIP TO HUMAN DECISION PROCESS
  - DIFFICULTY EXPLAINING RATIONALE UNDERLYING OUTPUT DECISIONS
  - SOME DIFFICULTY IN TESTING, CHANGING, MAINTAINING PROGRAM
- O KBS TECHNOLOGY ALLOWS EXPERT SYSTEM AUTOMATION OF HUMAN DECISION PROCESS
  - DATABASE OF ABSTRACT DECISION RULES
  - COMPUTER MAKES INFERENCES FROM INPUTS AND RULE BASE
  - USER-FRIENDLY INTERFACE PROVIDES JUSTIFICATION FOR ANSWERS

PURPOSE OF CONFLICT RESOLUTION EXPERT SYSTEM

GIVEN:

- O PREDICTED CONFLICTS (POTENTIAL VIOLATIONS OF SAFE SEPARATION) BETWEEN AIRCRAFT
  - PREDICTED 15-30 MINUTES IN ADVANCE FROM FLIGHT PLAN DATA
  - CHARACTERIZED BY GEOMETRY, AIRCRAFT ALTITUDE, SPEED, INTENT, ETC.

PROVIDE:

- O RESOLUTION ALTERNATIVES IN ORDER OF PREFERENCE
  - AIRCRAFT TO BE DEVIATED
  - TYPE OF MANEUVER, INCLUDING PARAMETERS AND TIME OF EXECUTION
- O EXPLANATION OF RATIONALE UNDERLYING RECOMMENDATIONS

CONSIDERATIONS PERTINENT TO RESOLVING CONFLICTS

- Conflict Description
  - Conflict Situation
    - Geometry--crossing, headon, overtake, merging
    - Altitude realm--high or low
    - Relative position (horiz and vert), and velocity
    - Time/distance to point of first violation
    - Neighboring aircraft
  - Aircraft-Specific
    - Intent (at conflict and later)--arrival, etc.
    - Speed (general manouverability)
    - Maneuver status (at conflict) turning, etc.
    - Type--jet, piston, turboprop
    - Category--GA, air carrier, etc.
    - Ground speed
    - Metered? In queue?
- Constraints on Solution
  - Environmental
    - Terrain
    - Winds and severe weather
    - Special-use airspaces
    - Traffic flows, including E-W altitudes, etc.
    - Neighboring A/C
    - ATC restrictions--MVA, MEA, etc.
  - A/C-Specific
    - Service limits--maximum altitude
    - Performance limits--climb rate, speed, etc.
    - Pilot ability to comply (aircraft weight, etc.)
    - A/C not subject to maneuvers
    - Interlocks on maneuvers vs. current maneuver
    - Rules of the air
- Goals of Solution
  - Reduce number of conflicts
  - Don't preclude fallback solution if this one fails
  - Preserve right-of-way policy
  - Maneuver A/C not in arrival flow or metering queue
  - Minimize commands, no more vectors than one offset or dogleg
  - Preserve long-term intent--route bends, descent, etc.
  - Fuel efficiency
  - Preserve arrival ordering consistent with speed ordering
  - Minimize new delay consistent with metering goals
  - Try solutions in order of preference for given conflict
  - Rationale should be relatively transparent to controller
  - Provide lateral, long., vert., or radar type separation
  - Insensitivity to wind and A/C performance data uncertainty
  - Avoid risky solutions requiring controller monitoring

ORGANIZATION OF CFR KNOWLEDGE

- FACTS--DESCRIBE CONFLICT SITUATION
- EXPERT RULES--GENERATE LIST OF RESOLUTIONS IN ORDER OF PREFERENCE
- CONSTRAINTS--REJECT OR REORDER POSSIBLE SOLUTIONS BASED ON OTHER FACTORS
  - HIERARCHICAL ORDERING OF CONSTRAINTS
    - SHOWS RELATIVE IMPORTANCE OF CONSTRAINT VIOLATIONS
    - ALLOWS RELAXATION AND ACCEPTANCE OF MILD VIOLATIONS

FORM OF RESOLUTION EXPERT RULES

- GENERATE LIST OF RESOLUTIONS (AIRCRAFT AND MANEUVER) IN ORDER OF PREFERENCE
- INPUT FACTORS
  - TYPE OF CONFLICT (CROSSING, HEADON, MERGING, OVERTAKE)
  - INTENT (ARRIVAL, DEPARTURE, OVERFLIGHT)
  - SPEED
  - TIME-TO-CROSSING (CROSSING CONFLICTS ONLY)
  - TIME-TO-CONFLICT (CROSSING CONFLICTS ONLY)
  - CLIMB RATE (DEPARTURE INTENT)
- POSSIBLE MANEUVER CHOICES
  - ARRIVAL--SPEED REDUCTION, RESTRICTED DESCENT, VECTOR
  - DEPARTURE--RESTRICTED CLIMB, VECTOR
  - OVERFLIGHT--SPEED REDUCTION, VECTOR, CLIMB/DESCEND TO NEW ASSIGNED ALTITUDE

FORM OF RESOLUTION EXPERT RULES
(CONCLUDED)

- O TOTAL OF 27 RULES
  - FOUR CONFLICT TYPES
  - SIX INTENT COMBINATIONS (ARRIVAL-DEPARTURE, ETC.)
  - FURTHER SUBDIVISION OF CROSSING OVF-OVF, MERGING OVF-OVF, AND OVERTAKE ARV-ARV CASES
- O EXAMPLE EXPERT RULE

```
IF (CONFLICT-TYPE CROSSING -AC1 -AC2)
AND (INTENT DEPARTURE -AC1)
AND (INTENT OVERFLIGHT -AC2)
THEN (FACT *POSS* ((RESTR-CLIMB -AC1)(VECTOR -AC1)
     (VECTOR -AC2)(CHANGE-ALT -AC2)))
```

- O MANEUVER EXPANSION VIA SINGLE MAINTENANCE RULE

```
(VECTOR -AC) EXPANDS TO (RIGHT-TURN -AC)(LEFT-TURN -AC)
(CHANGE-ALT -AC) EXPANDS TO (CLIMB -AC)(DESCEND -AC)
```

RATIONALE FOR CURRENT SET OF CONFLICT RESOLUTION EXPERT RULES

O CROSSING CONFLICT (AIRCRAFT IS PRIMARY FACTOR)

- AIRCRAFT--PREFERENCE BASED ON INTENT, IF SAME, MANEUVER THE ONE FARTHER AWAY (ARV, OVF) OR SLOWER CLIMBER (DEP)
- MANEUVER--PREFER ALTITUDE CHANGE OR RESTRICTION TO ACHIEVE CLEAR VERTICAL SEPARATION UNTIL AFTER HORIZONTAL CROSSING, EXCEPT PREFER SPEED REDUCTION, IF OVF-OVF AND TIME-TO-CONFLICT GREATER THAN 20 MINUTES

O HEADON CONFLICT (MANEUVER IS PRIMARY FACTOR)

- MANEUVER--PREFER VECTOR TO GAIN CLEAR LATERAL SEPARATION
- AIRCRAFT--PREFERENCE BASED ON INTENT, IF SAME, MANEUVER FASTER A/C

O MERGING CONFLICT (AIRCRAFT IS PRIMARY FACTOR)

- AIRCRAFT--PREFER SLOWER ONE TO ACHIEVE NECESSARY SPEED ORDERING
- MANEUVER--PREFER VECTOR TO MERGE SLOWER IN BEHIND FASTER AIRCRAFT
- EXCEPTION--IF OVF-OVF AND TIME-TO-CONFLICT GREATER THAN 20 MINUTES PREFER SPEED REDUCTION FOR FASTER A/C

O OVERTAKE CONFLICT (AIRCRAFT IS PRIMARY FACTOR)

- AIRCRAFT--PREFERENCE BASED ON INTENT, IF SAME, MANEUVER FASTER AIRCRAFT
- MANEUVER--PREFER VECTOR FOR CLEAR LATERAL SEPARATION, EXCEPT PREFER SPEED REDUCTION, IF SMALL SPEED DIFFERENCE (ARV, ARV)

CONSTRAINT RULES CURRENTLY USED IN CFR EXPERT SYSTEM

- O HIERARCHICAL ORDERING
  - SEVERE (FOUR RULES)
    - -- DON'T CLIMB/DESCEND IF SOMETHING ABOVE/BELOW
    - -- DON'T LEVEL OFF IF DEPARTURE/ARRIVAL AND SOMETHING BELOW/ABOVE
  - MODERATE (FIVE RULES)
    - -- AVOID TURNING RIGHT/LEFT IF SOMETHING TO RIGHT/LEFT
    - -- AVOID CLIMBING AIRCRAFT IF WITHIN 3,000 FEET OF SERVICE CEILING
    - -- AVOID TURNING RIGHT/LEFT IF TIME-TO-CONFLICT LESS THAN 7 MINUTES
  - MILD (FOUR RULES)
    - -- UNDESIRABLE TO MANEUVER AIRCRAFT IN METERING QUEUE
    - -- UNDESIRABLE TO TURN RIGHT/LEFT IF ROUTE BENDS LEFT/RIGHT
    - -- UNDESIRABLE TO CLIMB IF INTENT CHANGE OVERFLIGHT TO ARRIVAL
- O REORDERING OF SOLUTIONS
  - NO VIOLATIONS, ONLY MILD, AT MOST MODERATE, SOME SEVERE
  - ORIGINAL PREFERENCE ORDER IS PRESERVED AMONG SOLUTIONS WITH GREATEST VIOLATION IN SAME CATEGORY

CAPABILITIES OF CURRENT SOFTWARE IMPLEMENTED ON COMMAND AND MANAGEMENT INFORMATION SYSTEMS (CAMIS) LAB

- O EXPERT SYSTEM FOR RESOLVING CONFLICTS
  - APPLIES RULES TO FACTS DESCRIBING A TWO-AIRCRAFT CONFLICT SCENARIO
  - RECOMMENDS SOLUTION ALTERNATIVES IN ORDER OF PREFERENCE
- O EXPLANATION OF RESULTS
  - WHICH RULES WERE ACTIVATED
  - HOW GIVEN FACTS LED TO INDICATED SOLUTION
- O GRAPHICAL PRESENTATION OF CONFLICT SCENARIOS
  - ROUTE AND ALTITUDE PROFILES ON RAMTEK COLOR GRAPHICS DISPLAY
- O RULE BASE DEVELOPMENT AIDS
  - DEPICT RULE INTERACTIONS DUE TO COMMON INPUT AND OUTPUT CLAUSES
  - ALLOW RULE EDITING DIRECTLY IN LISP ENVIRONMENT

PHOTO INTELLIGENCE PROBLEM

- TOO MUCH IMAGERY
- TOO FEW TRAINED PHOTO INTERPRETERS AND INTELLIGENCE ANALYSTS
- COMPUTER VISION IS GOOD. HOW CAN IT BE USED:
    - IN THE SOFTCOPY WORKSTATION ENVIRONMENT
    - TO INCREASE PRODUCTIVITY RATHER THAN DISTRACT THE VIEWER
- PROBLEM DOMAIN
    - FY84: DETECT NEW MAN-MADE STRUCTURES IN THE WILDERNESS
    - FY85: CONSTRUCT BLUEPRINTS/MAPS/MODELS OF NEW BUILDINGS/TOWERS/SHIPS

SOLUTION

IN FY84 WE EXPECT TO HAVE A SET OF GENERAL PURPOSE COMPUTER VISION SOFTWARE TOOLS THAT CAN BE USED TO DETECT NEW MAN-MADE STRUCTURES IN THE WILDERNESS FROM PAIRS OF DIGITIZED AERIAL PHOTOS.

IN FY85 WE PLAN TO USE MANY OF THESE TOOLS TO COMPARE NEW IMAGERY WITH SYNTHETIC IMAGERY PREDICTED FROM A 3-DIMENSIONAL SCENE MODEL. FURTHERMORE, WE PLAN TO USE THE CHANGES WHICH ARE DETECTED TO UPDATE THE SCENE MODEL.

IMAGE PROCESSING TECHNOLOGIES

- IMAGE ENHANCEMENT

  (IMAGE IN - BETTER IMAGE OUT)

USED TODAY

NOT USED TODAY

- IMAGE PROCESSING - PATTERN RECOGNITION

  (FEATURE EXTRACTION)

- COMPUTER VISION

  ASSIMILATION, MATCHING OF FEATURES
  TOWARD OBJECT RECOGNITION

- ARTIFICIAL INTELLIGENCE

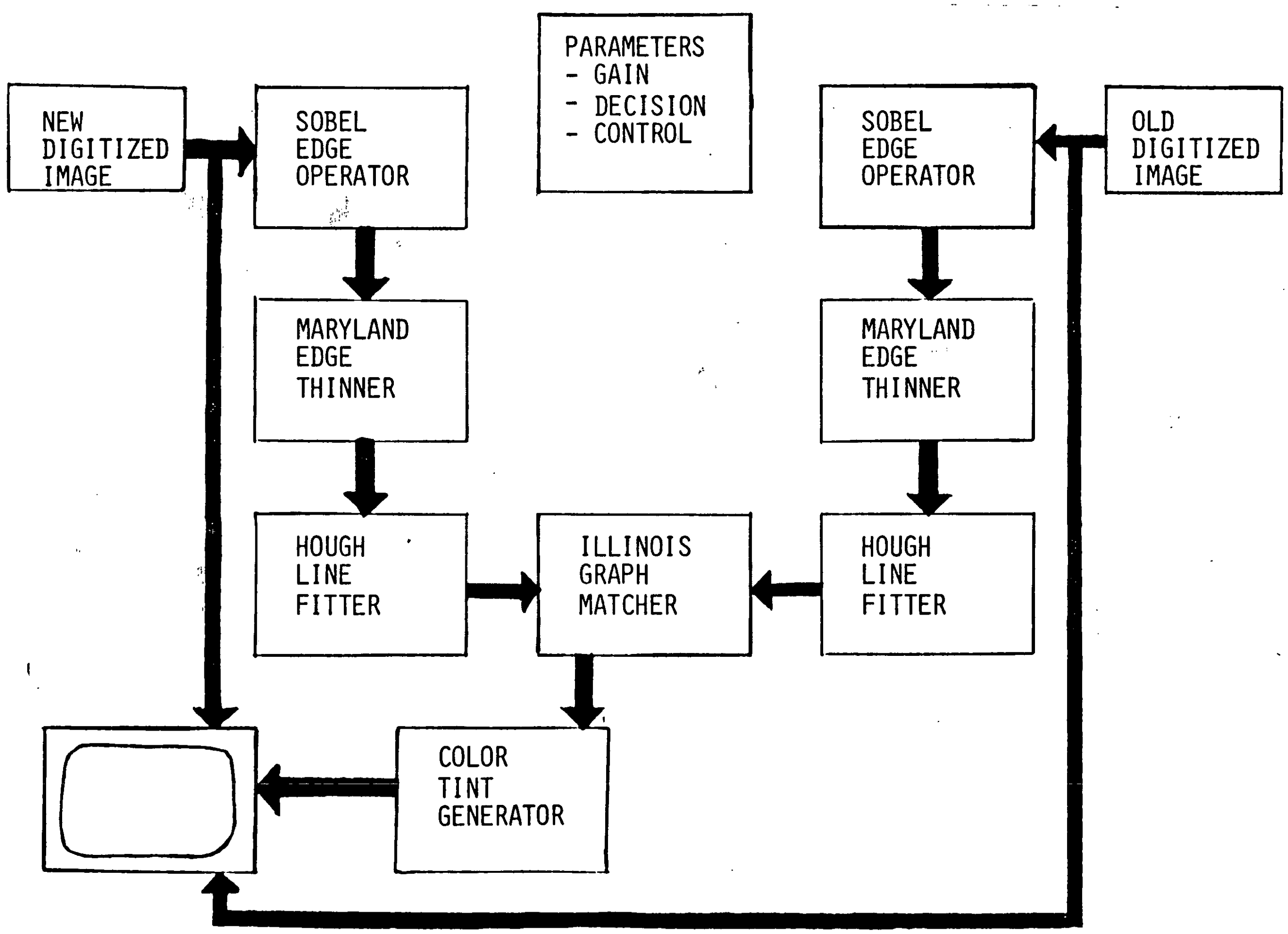
  SCENE INTERPRETATION
  RELATIONSHIPS BETWEEN OBJECTS IN A SCENE

TECHNICAL CHALLENGES OF IMAGERY DATA

- DIFFERENCES DUE TO VIEWING GEOMETRY
  - ALTITUDE
  - VIEWING ANGLE
  - LAND TOPOGRAPHY
- DIFFERENCES DUE TO LIGHTING EFFECTS
  - SUN ANGLE
  - SHADOWS
  - GLARE
  - BACK SCATTERED LIGHTING
- DIFFERENCES DUE TO OCCLUSION
  - BUILDING - BUILDING
  - BUILDING - GROUND
  - CLOUD COVER

Approved For Release 2008/08/22 : CIA-RDP86M00886R000500050006-9

FY84 APPROACH

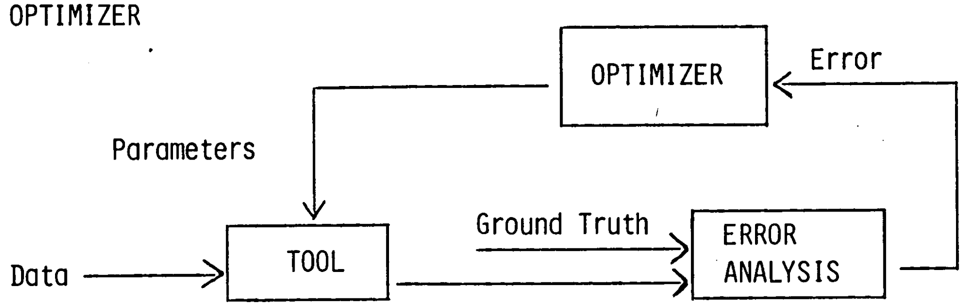


ADAPTIVE TRAINING

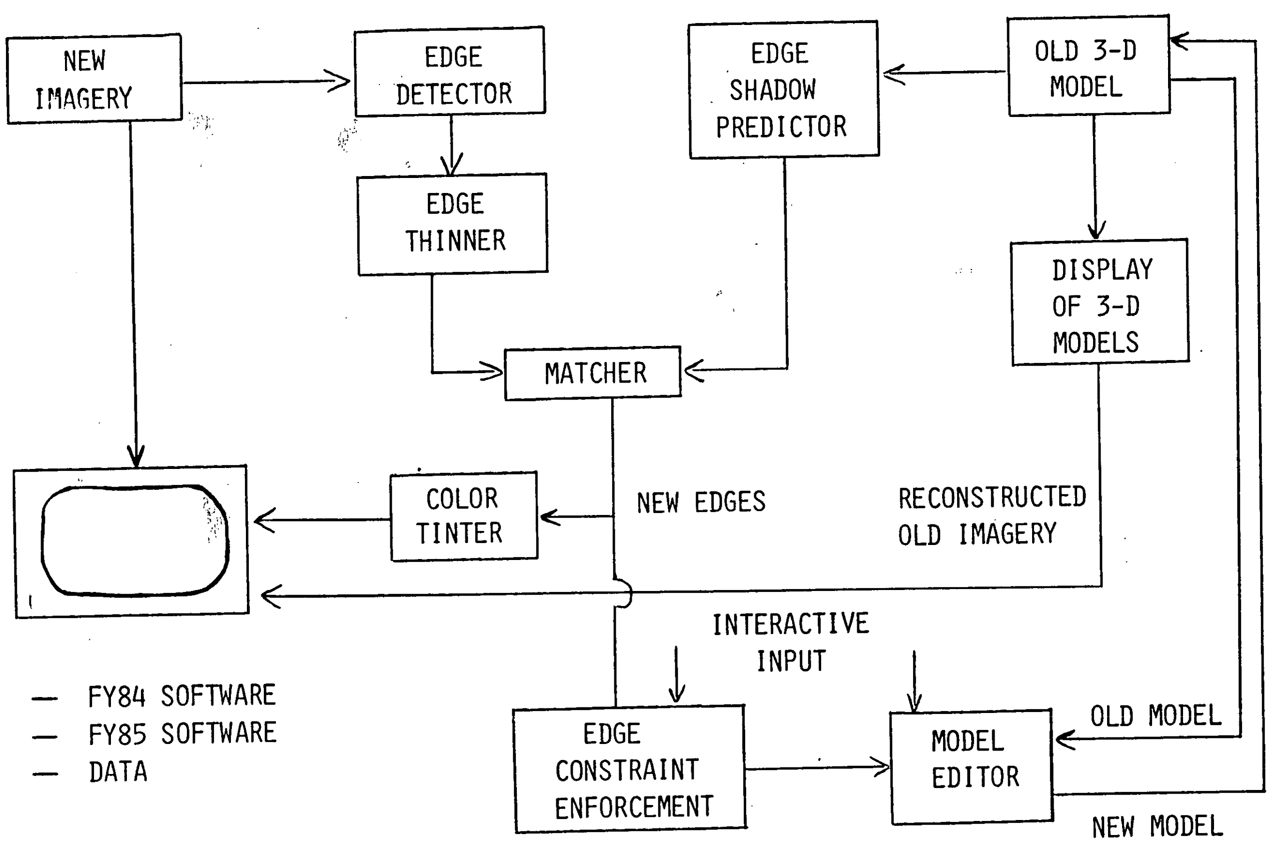
- EACH TOOL HAS SEVERAL GAIN/DECISION/CONTROL PARAMETERS
- DIFFICULT TO TUNE BY HAND FOR A GIVEN CLASS OF IMAGERY

REQUIREMENTS

- GROUND TRUTH
- ERROR ANALYSIS PROGRAM
- OPTIMIZER



FY85 APPROACH



FY84 TECHNOLOGY

- EDGE OPERATOR
  - LOW SENSITIVITY TO LIGHTING/VIEWING ANGLE
  - FACTOR OF 10 DATA REDUCTION
  - FAILS TO DETECT 5% OF ACTUAL "GOOD" EDGES
  - DETECTS "EXTRA" EDGES
- EDGE THINNER
  - REMOVES 90% OF "EXTRA" EDGES PRODUCED BY THE EDGE DETECTOR
  - FACTOR OF 3 DATA REDUCTION
  - REMOVES 5% OF THE "GOOD" EDGES
- LINE FITTER
  - SEPARATES MAN-MADE OBJECT EDGES FROM NATURAL EDGES
  - RESYNTHESIZES SOME OF THE LOST "GOOD" EDGES
  - FACTOR OF 5 DATA REDUCTION
  - SNOW/CLOUD COVER DOES NOT PRODUCE STRAIGHT LINES
- GRAPH MATCHER
  - DETECTS DIFFERENCES (IN THE STRAIGHT LINES PRODUCED FROM MAN-MADE OBJECTS)
  - LOW SENSITIVITY TO EXTRA/LOST EDGES

ADDITIONAL TECHNOLOGY

- DISPLAY OF 3-D MODELS WITH HIDDEN SURFACE REMOVAL
  - SOFTWARE (MODIFIED MOVIE BYU)
  - INPUT: 3-D MODEL OUTPUT: IMAGE
- EDGE/SHADOW PREDICTOR
  - ALGORITHMS EXIST (MUST BE PROGRAMMED)
  - INPUT: 3-D MODEL OUTPUT: EDGES
- EDGE CONSTRAINT ENFORCEMENT
  - ALGORITHMS EXIST (MODIFIED STRAIGHT LINE FITTER)
  - INPUT: EDGES OUTPUT: STRAIGHT/CURVED LINES
  - FITS EDGES TO LINES AND CURVES
  - MAKES EDGES PARALLEL, VERTICAL, EQUAL LENGTH, ETC.
- MODEL EDITOR
  - PARTIAL SOFTWARE (MODIFIED GRAPH EDITOR)
  - INPUT: INTERACTIVE + STRAIGHT/CURVED LINES + MODEL
  - OUTPUT: NEW MODEL
  - CONSTRUCT SIMPLE SOLID MODELS FROM PARALLEL EDGES
  - CAN COMBINE TWO SOLID MODELS TO FORM A NEW SOLID MODEL

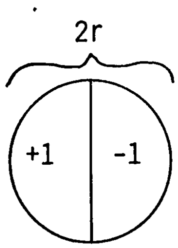
EXPECTED RESULTS

- FACTOR OF 10 INCREASE IN PHOTO INTERPRETER TASK THROUGHPUT
- A MITRE DEMONSTRATION SYSTEM THAT USES COMPUTER VISION TOOLS TO ASSIST AN INTELLIGENCE ANALYST TO INTERACTIVELY UPDATE A 3-DIMENSIONAL MODEL FROM NEW IMAGERY
- SYNTHESIS OF IMAGERY FROM OBLIQUE ANGLES NOT AVAILABLE TO THE SENSOR

GRADIENT BASED EDGE DETECTORS

- ESTIMATE THE GRADIENT OF THE IMAGE FUNCTION USING DISCRETE SPACIAL CONVOLUTION
- HYPOTHESIZE THAT EDGES PASS THROUGH POINTS WHERE THE MAGNITUDE OF THE GRADIENT VECTOR $Q_{a,b}$ IS LARGER THAN A THRESHOLD t.
- $$Q_{a,b} = \left[\sum_{i=-n}^{n} \sum_{j=-n}^{n} U_{i,j} P_{(a-i),(b-j)} \right]^2 + \left[\sum_{i=-n}^{n} \sum_{j=-n}^{n} V_{i,j} P_{(a-i),(b-j)} \right]^2$$
- SOBEL

U = a *

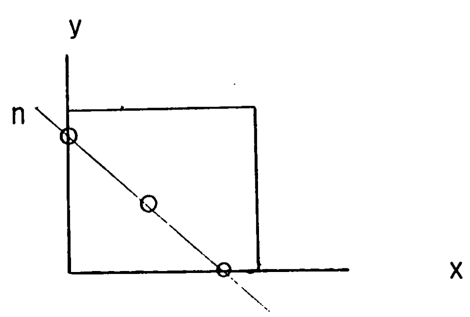


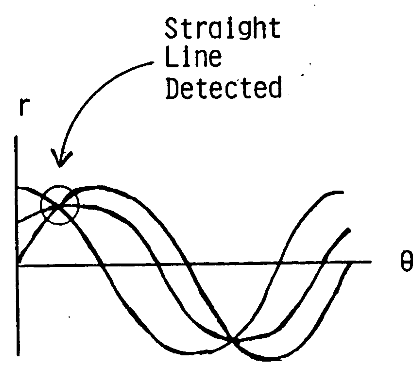
$$= \begin{matrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{matrix}; \quad V = \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix}$$

- PARAMETERS r, a, t

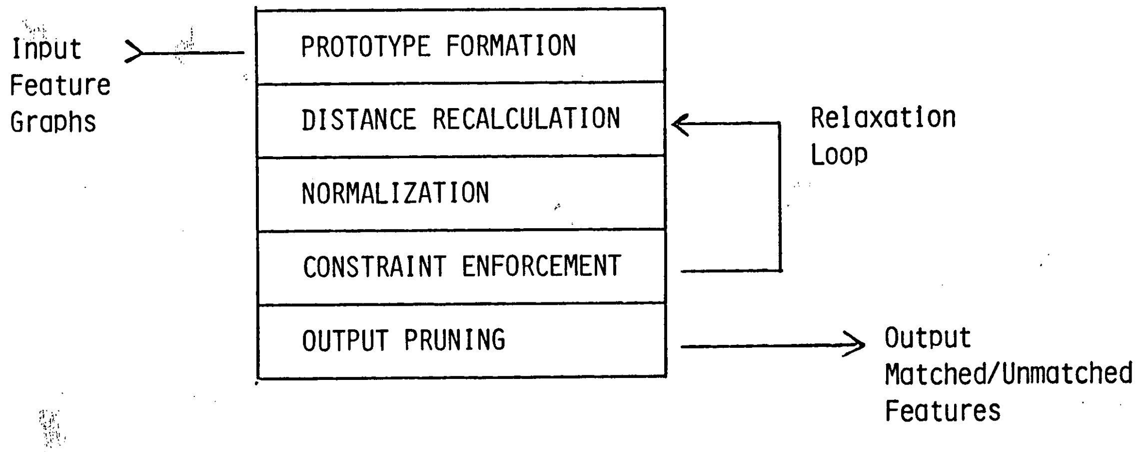
HOUGH TRANSFORM AND STRAIGHT LINE FITTING

- PARTITION SPACE INTO n by n CELLS
- HOUGH TRANSFORM $x, y \longrightarrow r, \theta \quad r = x \cdot \cos\theta + y \cdot \sin\theta$
- ACCUMULATOR ARRAY
- THRESHOLD t
- PARAMETERS n, t, $\Delta\theta$





FEATURE GRAPH MATCHING



HUMAN FACTORS DESIGN OF EXPERT SYSTEMS

IR&D UPDATE

Frank Stech
Joseph Schmuller

The MITRE Corporation

10 May 1984

Approved For Release 2008/08/22 : CIA-RDP86M00886R000500050006-9

HUMAN FACTORS DESIGN OF EXPERT SYSTEMS

- Issue: Expert Systems (ES) are designed to capture, reproduce, and distribute human expertise repackaged as computer programs.

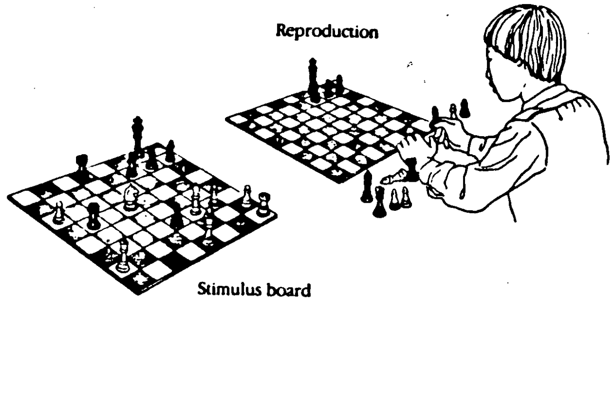
- Problems:
  - How can the ES designer capture human expertise accurately, completely, and efficiently?
  - How can the ES designer assess components of human expertise to improve subobtimal components?
  - How can the ES designer reassemble the human and enhanced components to represent expertise precisely?

TECHNIQUES AND TOOLS

• Expert Modeling Methods:	(Applicable to IR&D)
– Expert-Novice Comparisons	√
– Expert Protocol Analysis	√
– Information Processing Experiments	√
– Simulations	√
– Field Observations	
– Developmental Studies	
– Cross-cultural Comparisons	
– Historical Comparisons	

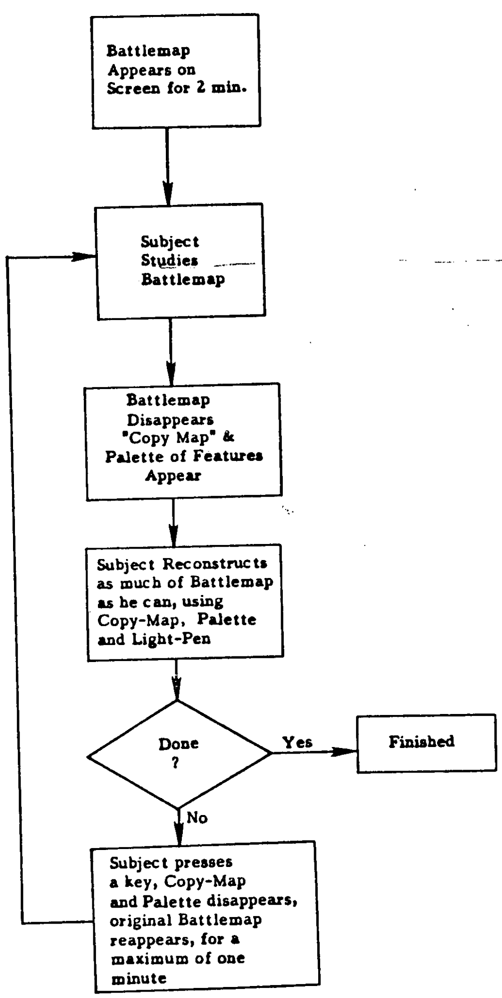
TECHNIQUES AND TOOLS (CONCLUDED)

- Tools
  - Chronometric measures (e.g., reaction time, processing time, chunking)
  - Multidimensional categorization analysis (e.g, scaling, clustering)
  - Subjective probability analysis (e.g., Non-Bayesian probability revision)
  - Problem-solving (e.g., accuracy, sequences, relationships)
  - Multiple regression (e.g., input-output trace, information integration modeling)

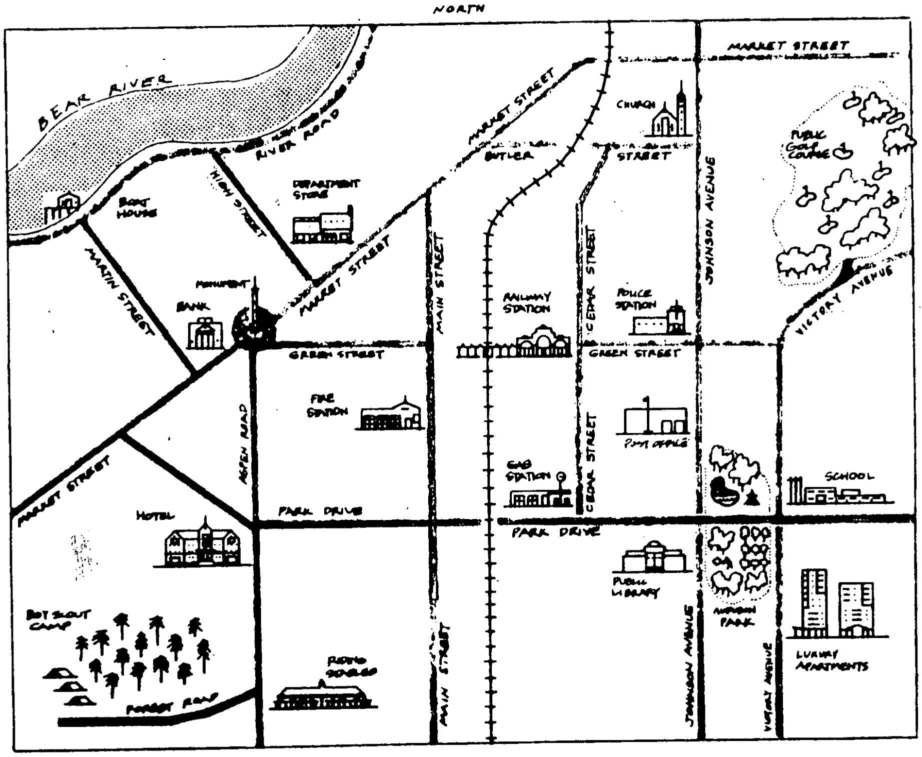

Reproduction
Stimulus board

PROTOTYPE ASSESSMENT: TACTICAL MAP BATTLEFIELD READING

- Methodology: Chunking (Chess Experts) applied to tactical maps
  - Copying maps
  - Reconstructing maps from memory
  - Estimating classes and overall situation
- Stimuli
  - Meaningful, semi-meaningful, and anomalous tactical maps
  - Varied map symbology; e.g., unit symbols, unit designation, unconventional symbols, chess symbols
- Data: Interplacement times, glances, gaze, symbol placement order, protocols

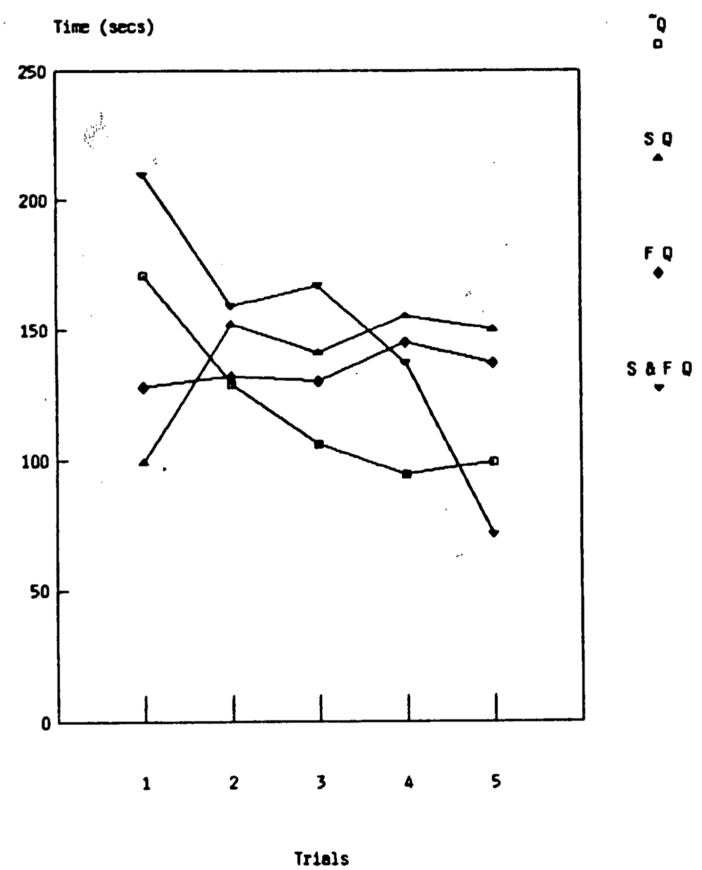

Battlemap
Appears on
Screen for 2 min.
Subject
Studies
Battlemap
Battlemap
Disappears
"Copy Map" &
Palette of Features
Appear
Subject Reconstructs
as much of Battlemap
as he can, using
Copy-Map, Palette
and Light-Pen
Done
?
Yes
Finished
No
Subject presses
a key, Copy-Map
and Palette disappears,
original Battlemap
reappears, for a
maximum of one
minute

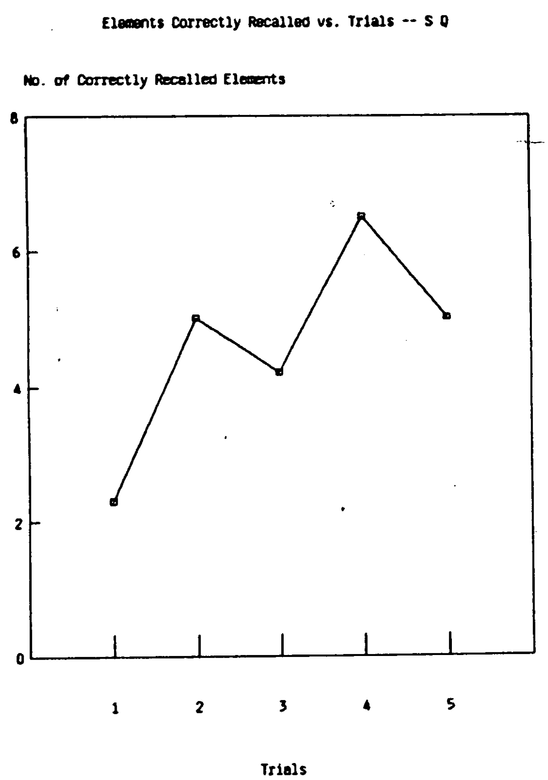
NORTH

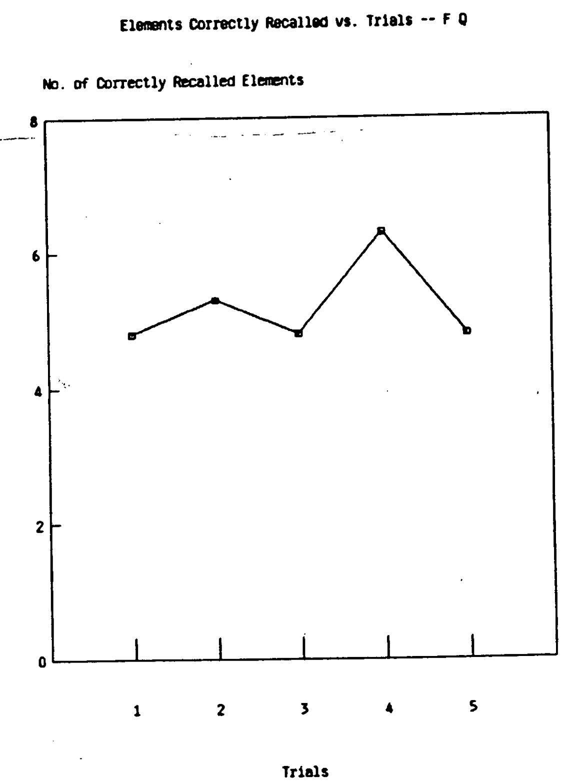

BEAR RIVER
RIVER ROAD
BOAT HOUSE
HIGH STREET
DEPARTMENT STORE
MARKET STREET
MARTIN STREET
MONUMENT
BANK
GREEN STREET
FIRE STATION
ASPEN ROAD
MARKET STREET
PARK DRIVE
HOTEL
BOY SCOUT CAMP
FOREST ROAD
MAIN STREET
MARKET STREET
BUTLER
STREET
CHURCH
MARKET STREET
PUBLIC GOLF COURSE
JOHNSON AVENUE
CEDAR STREET
RAILWAY STATION
POLICE STATION
GREEN STREET
VICTORY AVENUE
POST OFFICE
GAS STATION
SCHOOL
PARK DRIVE
PUBLIC LIBRARY
LUXURY APARTMENTS
JOHNSON AVENUE
VICTORY AVENUE
MAIN STREET

PILOT STUDY

Reconstruction Time vs, Trials







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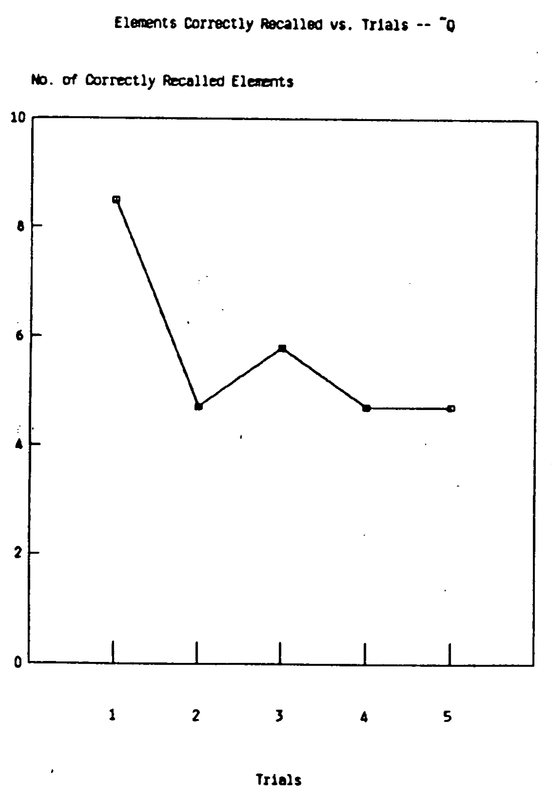

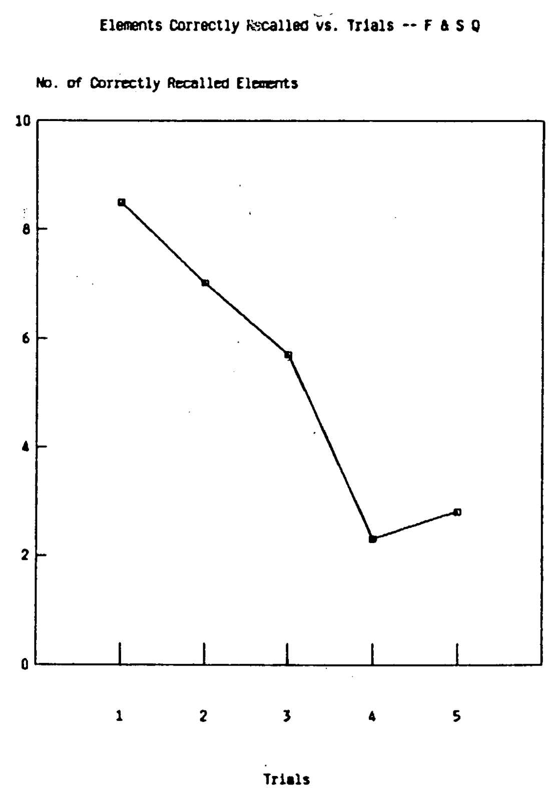

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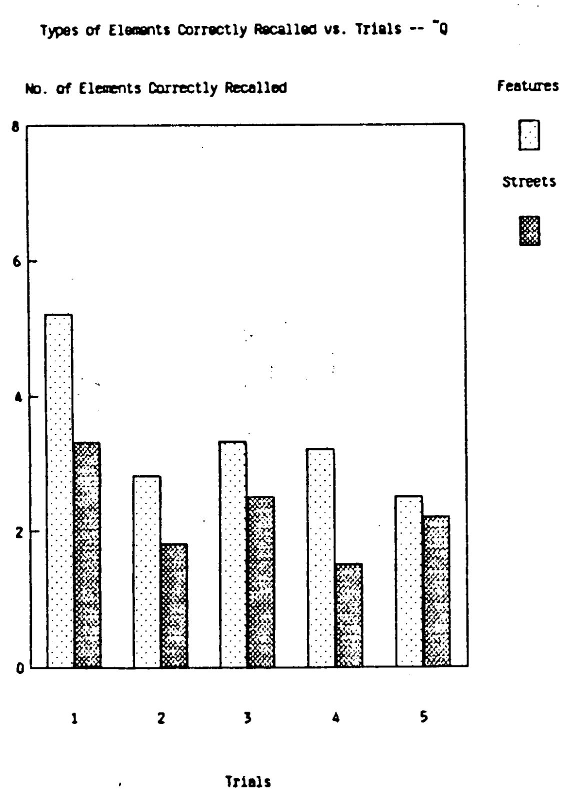
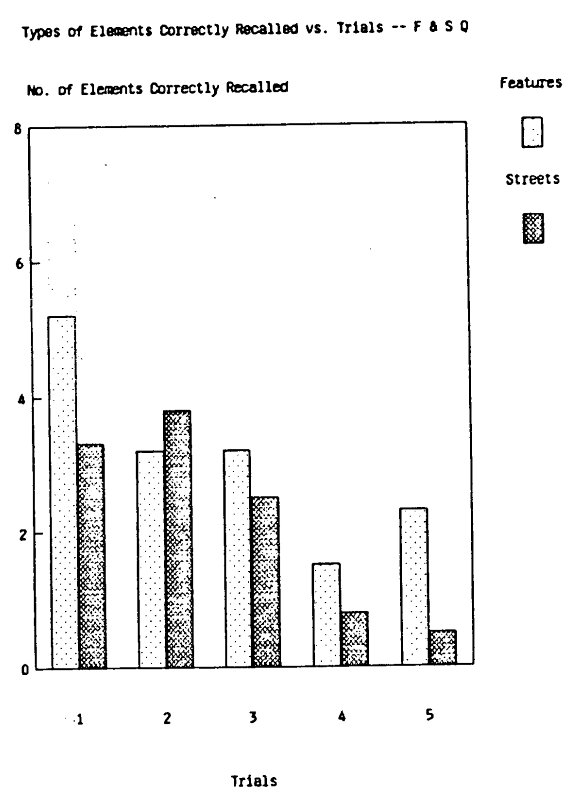
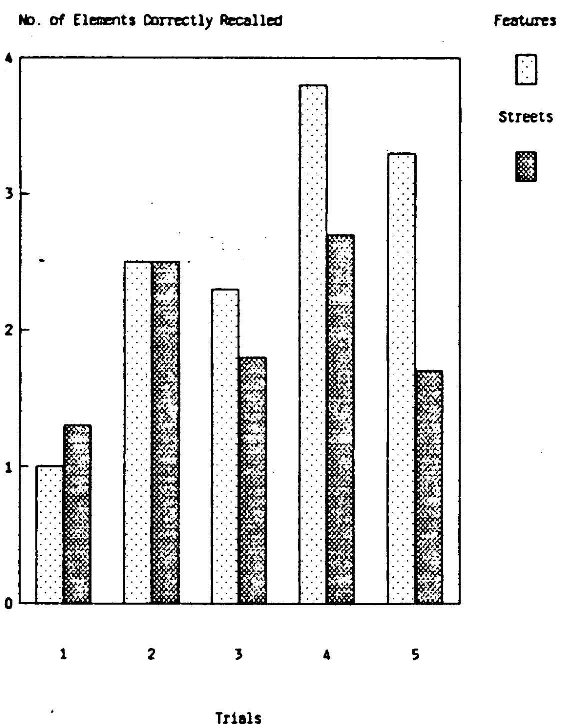
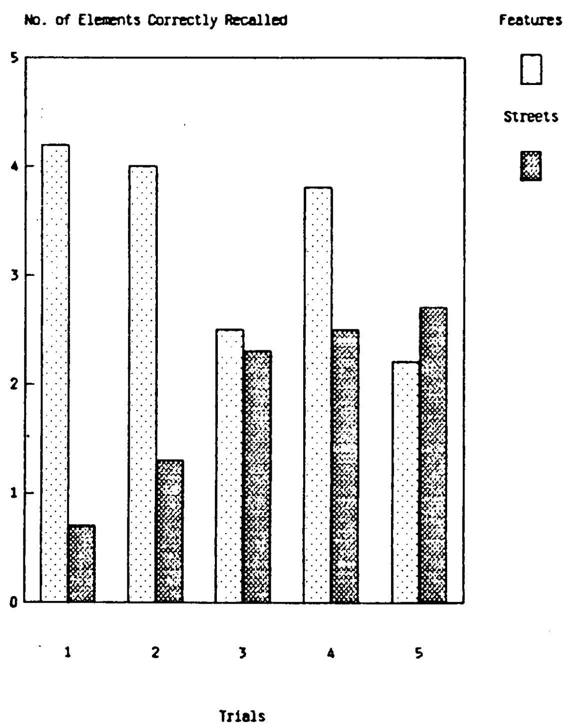

Types of Elements Correctly Recalled vs. Trials -- ¯Q
No. of Elements Correctly Recalled
Features
Streets
8
6
4
2
0
1
2
3
4
5
Trials


Types of Elements Correctly Recalled vs. Trials -- F & S Q
No. of Elements Correctly Recalled
Features
Streets
8
6
4
2
0
1
2
3
4
5
Trials

Types of Elements Correctly Recalled vs. Trials -- S Q



Types of Elements Correctly Recalled vs. Trials -- F Q



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PILOT STUDIES

- Study 1: Map Reading
  - Attention affects chunking
  - Chunks reflect pattern recognition
    - Memory/Learning curves
- Study 2: Map Assessment
  - Chunks relate to categories
  - Categories relate to summaries
  - Summaries relate to assessments

PILOT STUDIES (CONCLUDED)

- Study 3: Summary Composition
  - Report chunking
  - Covariation assessment
  - Availability effects

EXPERIMENTAL SERIES

- Tactical battlemap reading: What are the basic elements and relationships?

- Tactical battlemap assessment: What is the transfer function from symbolic map input to verbal/textual assessment output?

- Tactical summaries composition: How are tactical reports transformed and integrated into tactical assessments and summaries?

- Map and report integration and assessment: How are tactical reports integrated with battlemap data and transformed into situation assessments?

- Dynamic assessment: How does changing information (reports and maps) impact on analyst's assessments?

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ANALYST
A Knowledge-Based
Intelligence Support System

JTF Demonstration

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What Is ANALYST?

ANALYST is an Intelligence Support System...

- Targeted for Army Corps and Allied Tactical Operations Centers (Air Force)
- Supports All Source Sensor Fusion and Primary Information Request Processing
- Is Capable of Dynamic Refinement of Findings from New Data

...Composed of Integrated Expert System Techniques

- Both Data Driven and Request Driven
- Uses Both Hierarchical and Spatial Data Structures
- Employs Procedural, Propositional, and Iconic (Image) Knowledge Structures
- Maintains Truth Justifications
- Includes Knowledge-Engineering Tools

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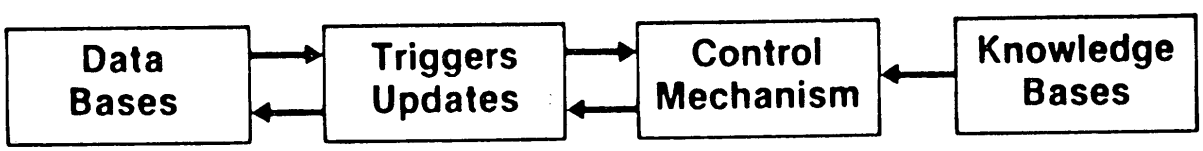
Expert Systems



- Use a Knowledge-Base of Rules-of-Thumb Provided by Experts
- Capture Fundamental Principles of the Problem Domain as Well as General Methodology
- Solve Complex Problems Well
- Can Interact Intelligently with the User
- Are Useful for Interpretation, Diagnosing, Predicting, Analyzing, Consulting

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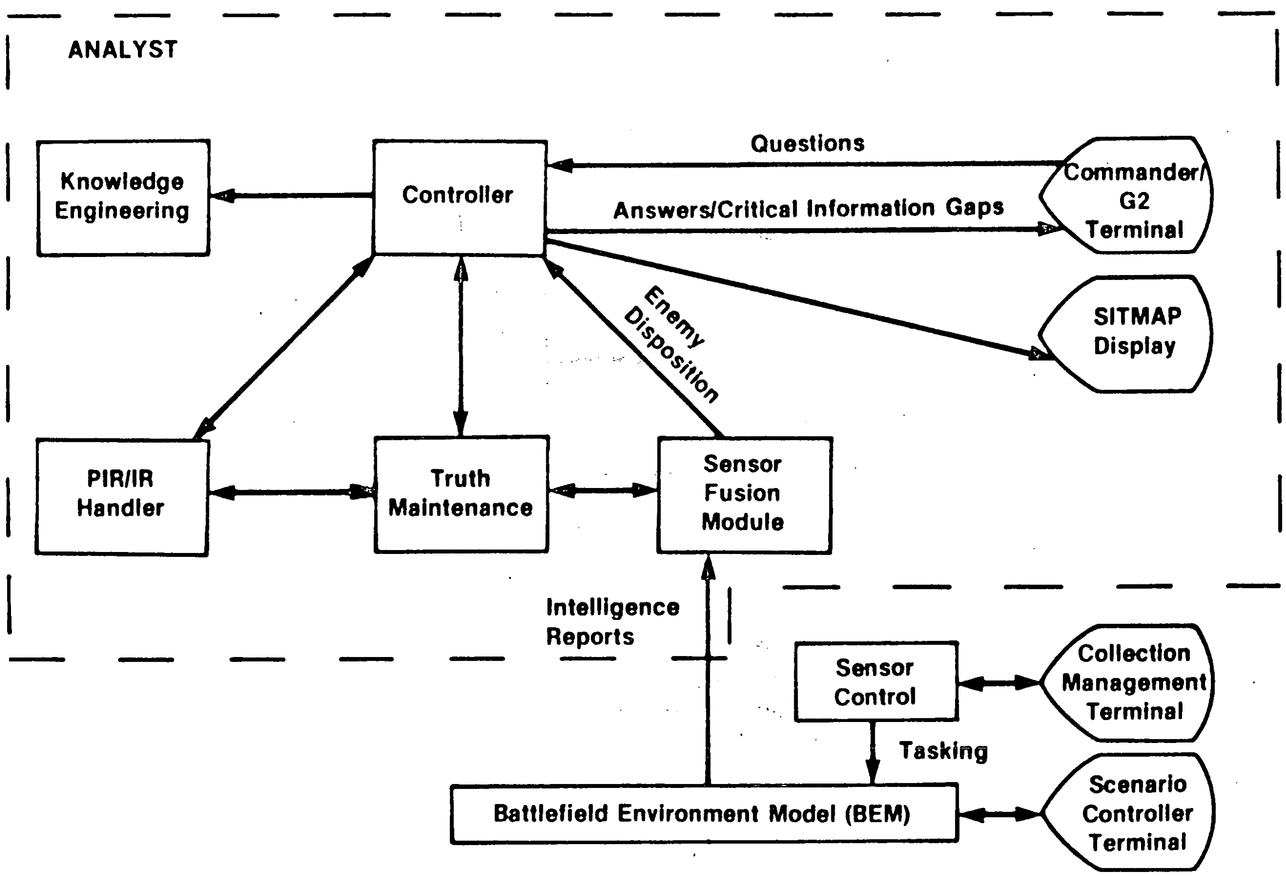
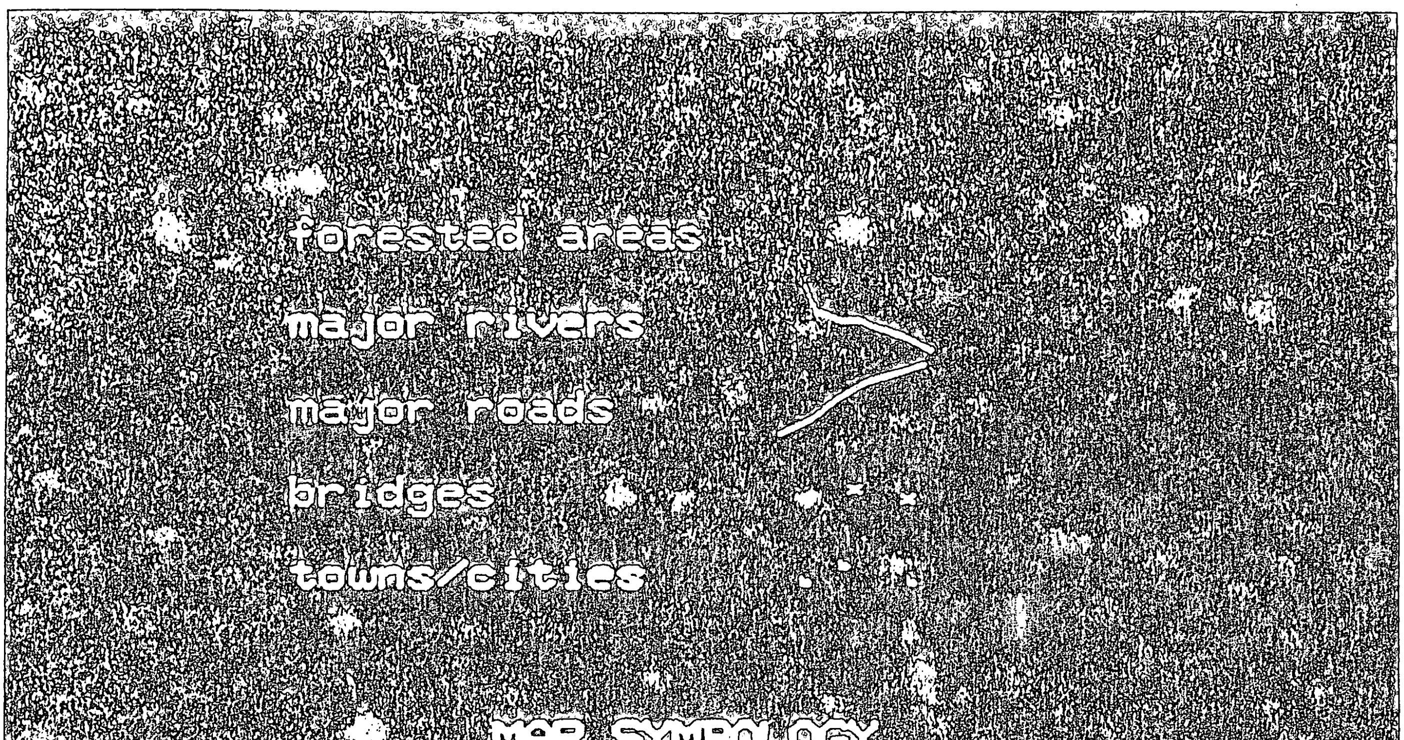
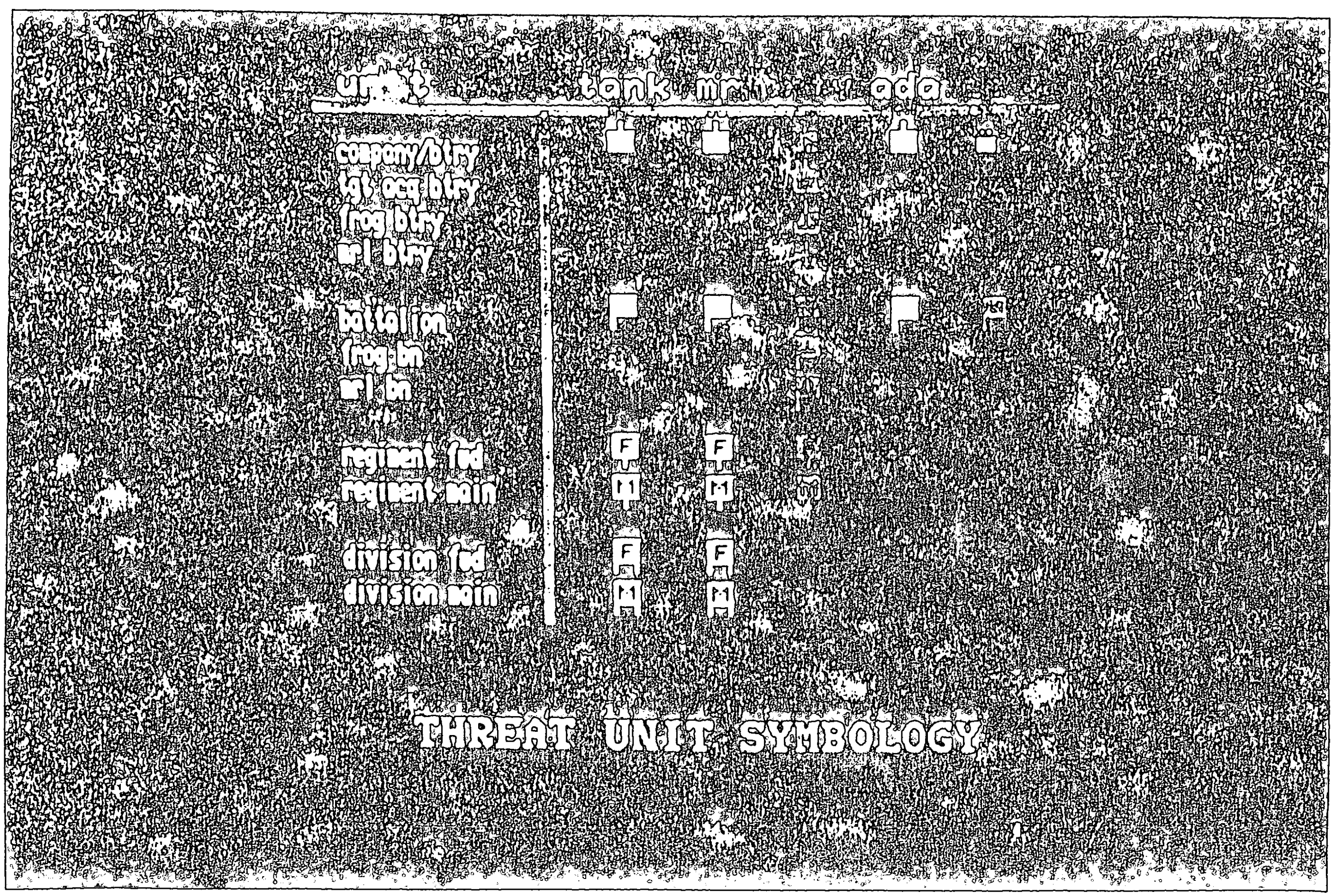
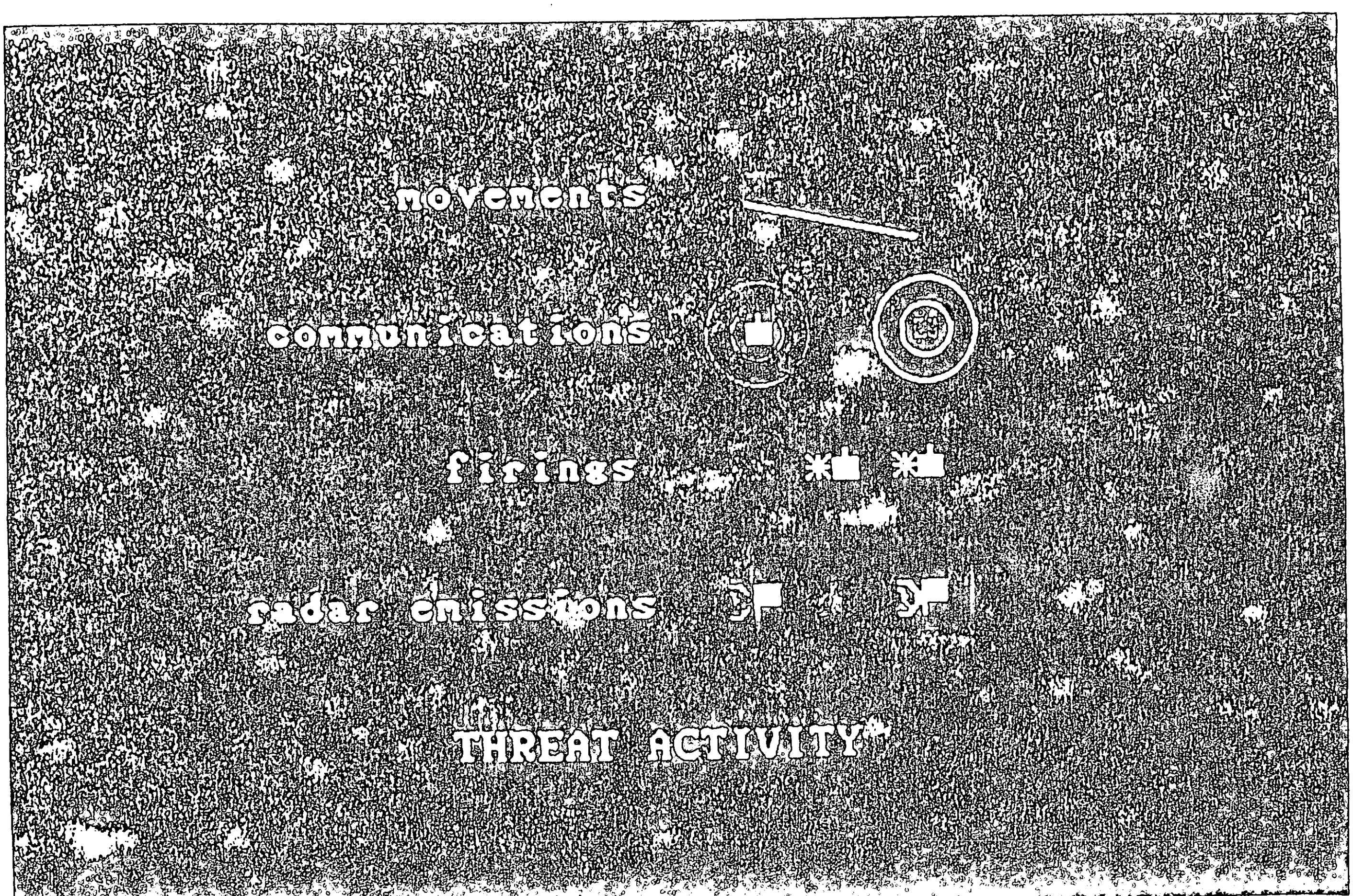
ANALYST Architecture




forested areas
major rivers
major roads
bridges
towns/cities
MAP SYMBOLOGY


unit
tank
mr
ada
company/btry
tgt acq btry
frog btry
mrl btry
battalion
frog bn
mrl bn
regiment fwd
regiment main
division fwd
division main
THREAT UNIT SYMBOLOGY


movements
communications
firings
radar emissions
THREAT ACTIVITY

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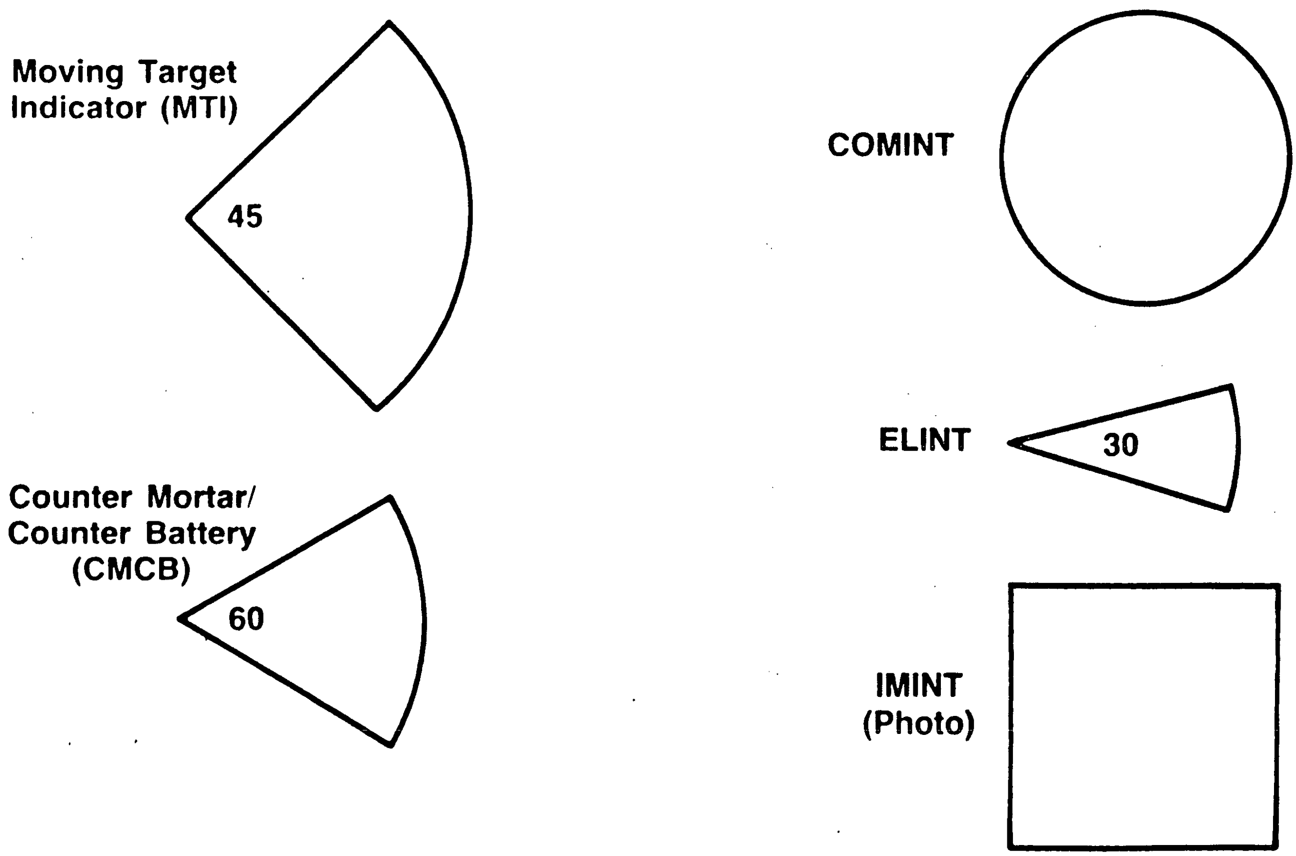
Sensor Coverage Symbology



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Threat Modeling

- Experimental Boundaries
  - Soviet/WP Division from SCORES
  - Company/Battery Resolution
  - Stylized Terrain
- Emphasis on Activities
  - Movement
  - Emissions
- Behavior Modeling
  - Object-Oriented Programming
  - Activities are Rule-Based

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Sensor Modeling

- Current Experimental Boundaries
  - Corps/Division Orientation
  - Continuous Resource Availability
  - Optimal Communications
  - No Formal Models
- Emphasis on Geographic Coverage
  - Platform Flight Paths, Time-on-Station
  - Ranges, Coverage Angles
- Interactive Tasking – Sensor Control Station
  - View "TAKE"
  - Reposition Sensors

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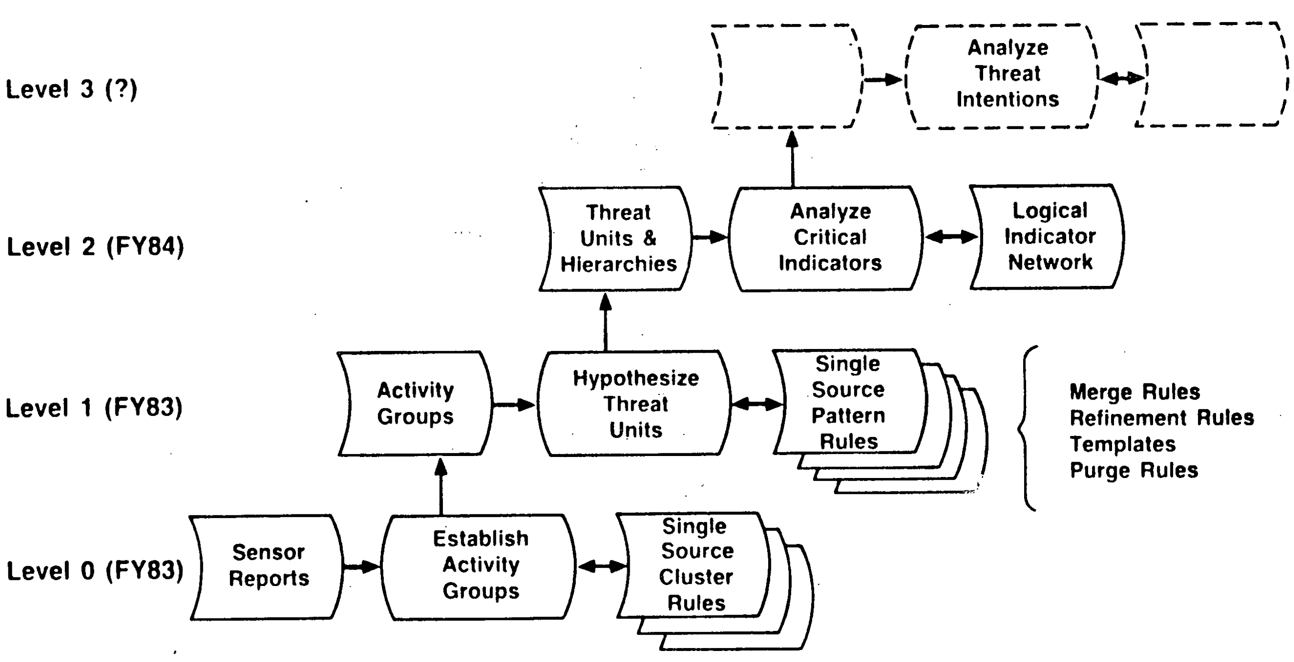
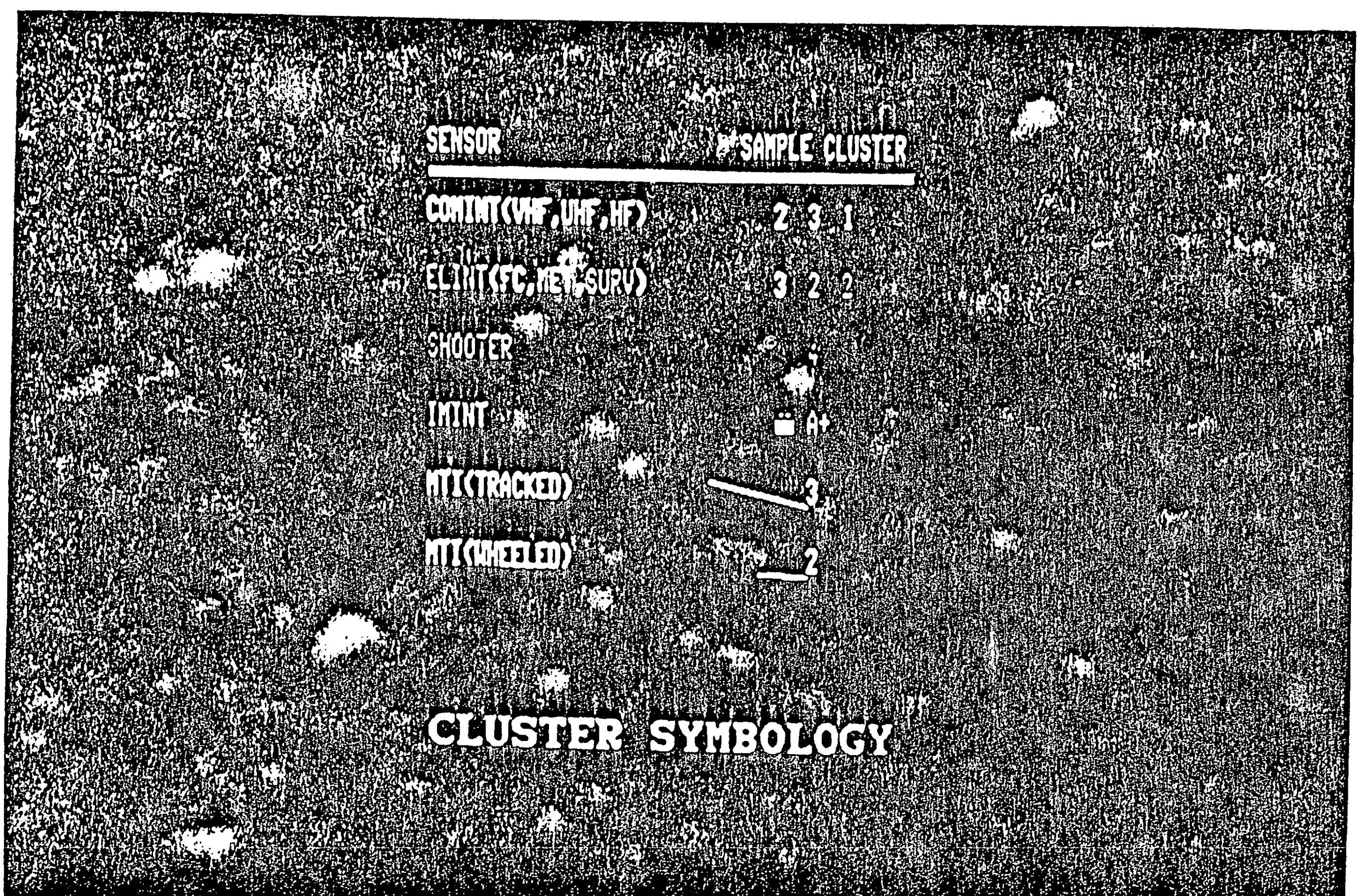
Levels of ANALYST Reasoning




SENSOR
SAMPLE CLUSTER
COMINT(VHF,UHF,HF)
2 3 1
ELINT(FC,MET,SURV)
3 2 2
SHOOTER
IMINT
A+
MTI(TRACKED)
3
MTI(WHEELED)
2
CLUSTER SYMBOLOGY

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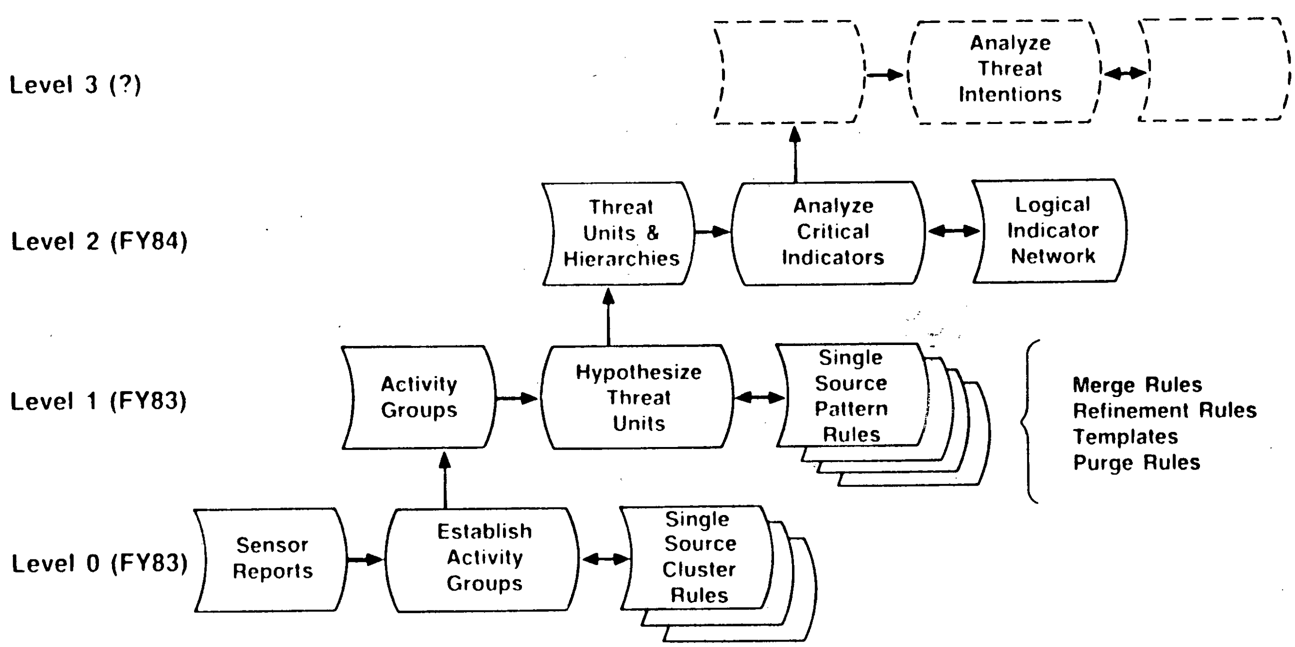
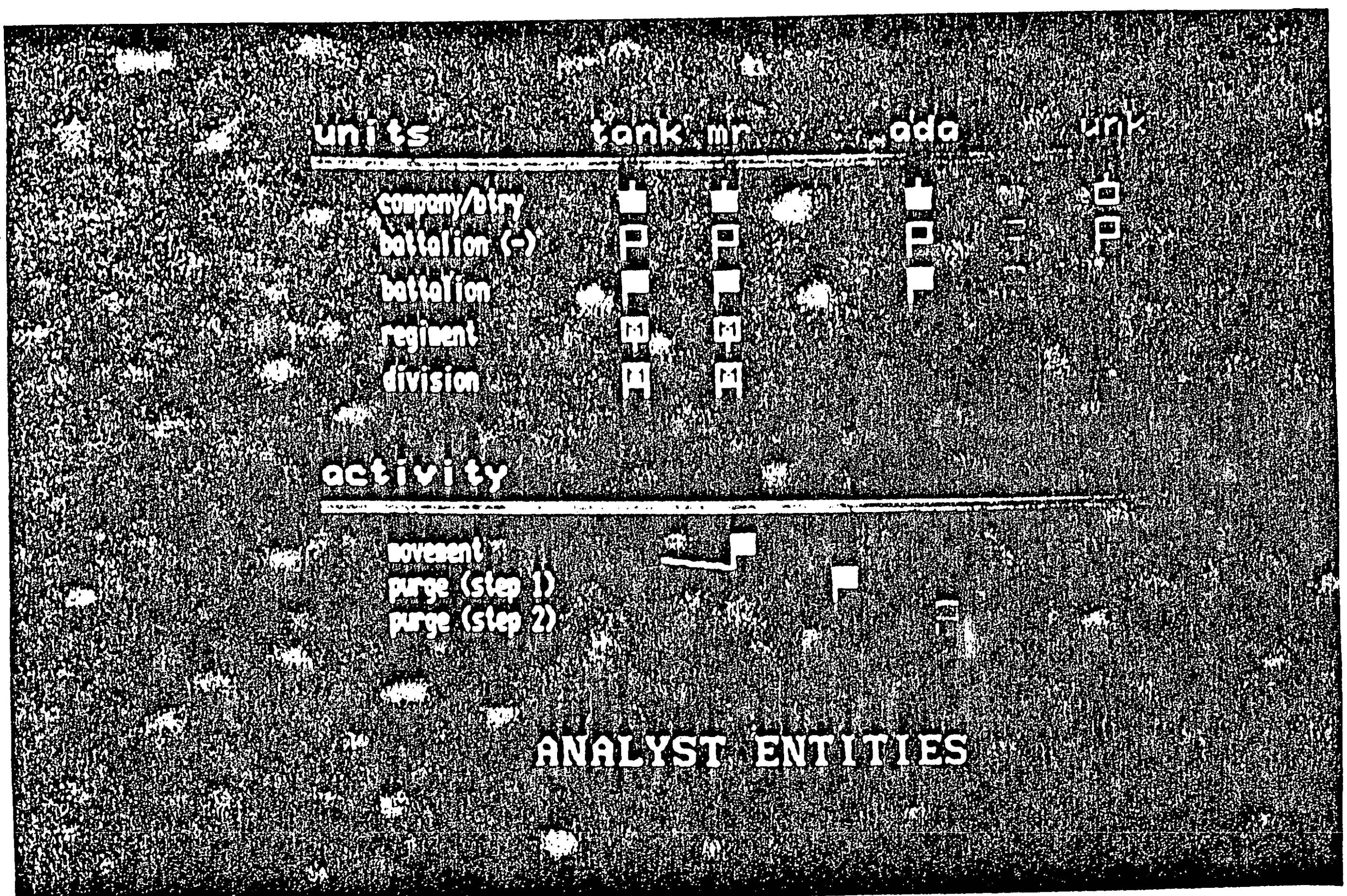
Levels of ANALYST Reasoning




units
tank
mr
ada
unk
company/btry
battalion (-)
battalion
regiment
division
activity
movement
purge (step 1)
purge (step 2)
ANALYST ENTITIES

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Results

With 35% coverage

- ANALYST locates over 70% of the active enemy battalions
- Accuracies average 750 meters circular error probable (CEP)
- General force movement trends are detectable
- System tracked individual movement of 15% of the regimental and battalion command posts

With 20% coverage

- Over 50% of the active battalions located
- General force movement trends still discernible

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ANALYST System Characteristics

Capabilities

- Knowledge-Based
  - Can View On-Going Analytical Processes
  - Can Edit Rule-Base On-Line
  - Straightforward Architecture
  - Keys on Patterns of Activity
- Processing
  - Stays Abreast of Battlefield Dynamics
  - Real-Time Speed
  - Multiple-Source
  - Does Not Require a Mainframe Environment

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ANALYST System Characteristics

Limitations

- Idiot-Savante Nature
  - — Totally Dependent on "Expert" Rules
  - — Does Not Introspect
- Single Scenario Development
- Needs Operational Knowledge Instead of Demonstration Knowledge