N87-29142

P-19

EXPERT SYSTEM FOR IMAGING SPECTROMETER ANALYSIS RESULTS

JPL

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IMAGE PROCESSING APPLICATIONS
& DEVELOPMENT SECTION

JET PROPULSION LABORATORY

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IMPLEMENTATION REQUIREMENTS

- INTEGRATION OF SYMBOLIC AND NUMERICAL TECHNIQUES
- PORTABILITY AND SIZE
- EFFICIENCY OF OPERATION

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STAR
(SIMPLE TOOL FOR AUTOMATED REASONING)

- A LISP-LIKE SOFTWARE ENVIRONMENT FOR THE DEVELOPMENT AND OPERATION OF RULE-BASED EXPERT SYSTEMS
- IMPLEMENTED IN "C." APPROXIMATELY 7000 LINES SOURCE CODE
- SEMANTIC NETWORK REPRESENTATION OF FACTS AND RULES
- FACILITIES FOR INTERACTION WITH PROCEDURES AND DATA STRUCTURES CODED IN C

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STAR DATA STRUCTURES (UNITS)

	UNIT TYPE	EXAMPLES
(1)	NUMBER	100.4 -3.72
(2)	TOKEN	GRANITE FELDSPAR
(3)	STRING	"CLASTIC SEDIMENTARY ROCK"
(4)	LIST	[3.6 -4.88 5.0]
(5)	RECORD	{name -> CHLORITE member_of -> material_classification variety_of -> mica plots -> [^PLOT ^PLOT ^PLOT] }
(6)	EXPRESSION	add(10 20) compare(^PLOT calcite)
(7)	CONNECTION	^ROUTINE ^PLOT

```
{name -> MENU
 member_of -> function
 arguments -> []
 algorithm  ->
       [initialize()
        repeat(
          [set(current_time +(.current_time 1))
           determine_menu()
           repeat(
             [fetch_user_input()
              through(.current_menu menu_i
                [if(match_menu_item()
                    'break(break(apply(get(.menu_i to_call)[])))
                   ])
              output_menu()
              ])
           ])
        ]
 }
```

```
{name -> RULE_23A
 member_of -> ruleset_23
 mode -> single_test
 condition -> >(natural_abundance(.i) natural_abundance(.j))
 action -> [discourage(.j .region)]
 }

{name -> RULE_7F
 member_of -> ruleset_7
 mode -> single_application
 condition -> exists(.neighboring_minerals j likely_association(.i .j))
 action -> [encourage(.i .region)]
 }

{name -> RULE_8B
 member_of -> ruleset_8
 mode -> multiple_application
 condition -> >(size(.possibilities) 20)
 action -> [set(thresh -(.thresh 2)) eliminate_possibilities()]
 }
```

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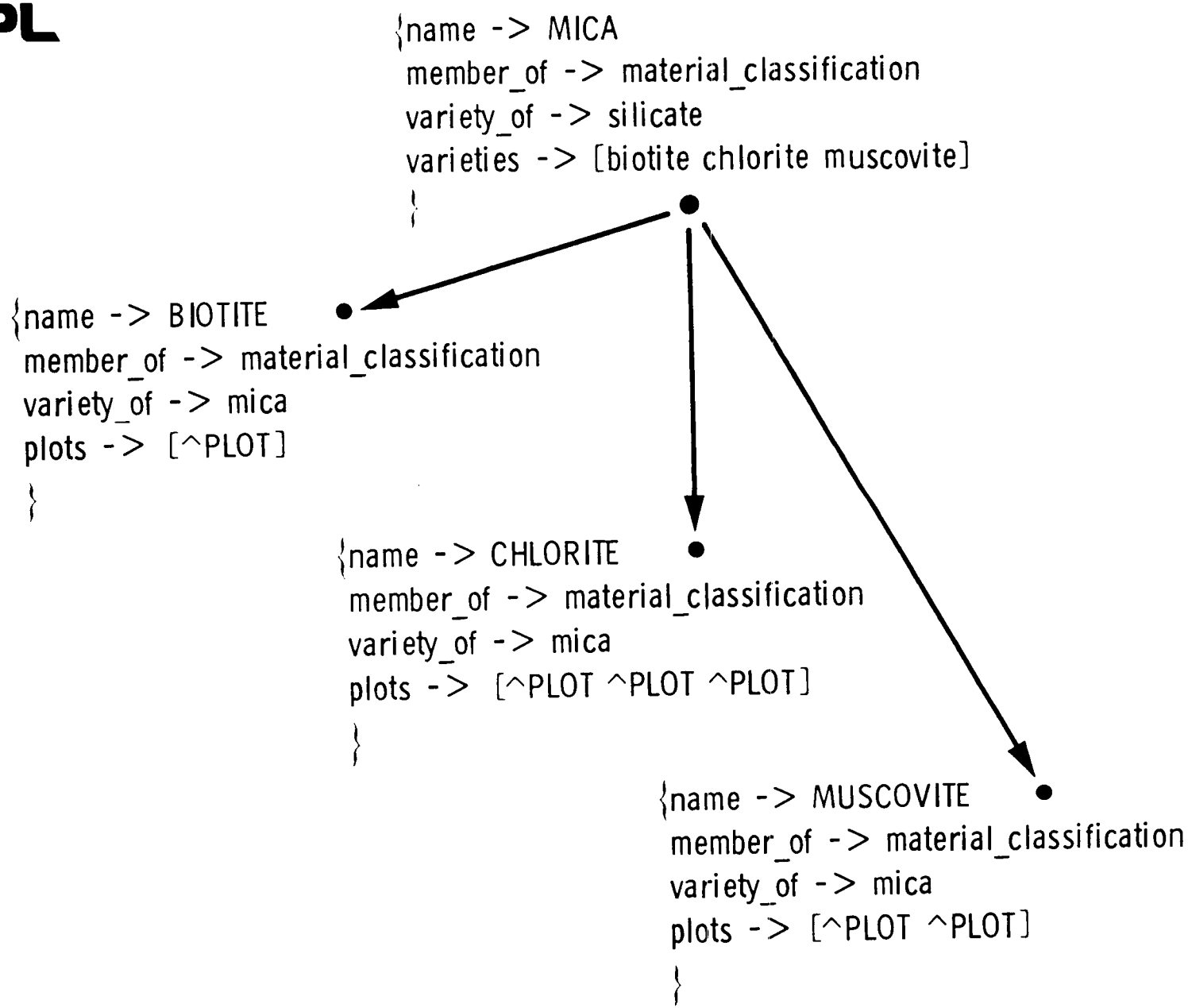
{name -> MICA
member_of -> material_classification
variety_of -> silicate
varieties -> [biotite chlorite muscovite]
}
{name -> BIOTITE
member_of -> material_classification
variety_of -> mica
plots -> [^PLOT]
}
{name -> CHLORITE
member_of -> material_classification
variety_of -> mica
plots -> [^PLOT ^PLOT ^PLOT]
}
{name -> MUSCOVITE
member_of -> material_classification
variety_of -> mica
plots -> [^PLOT ^PLOT]
}

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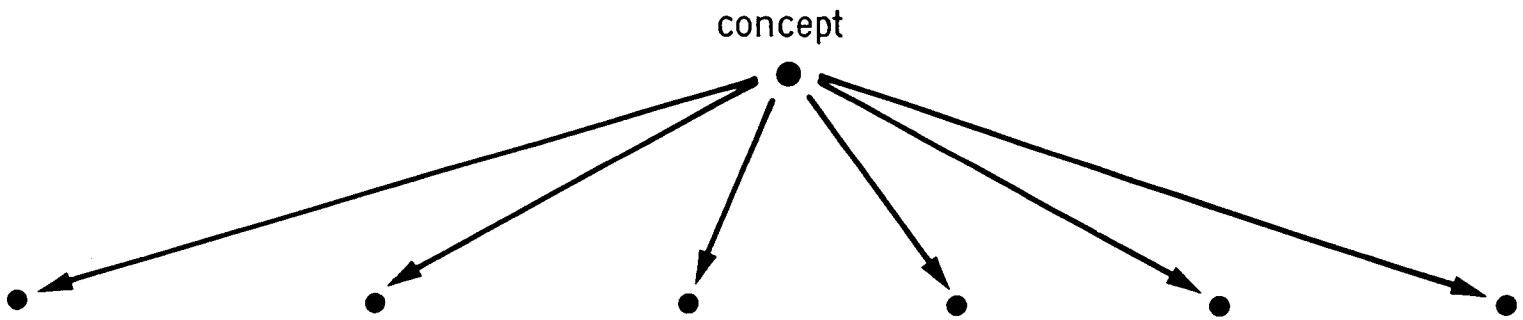
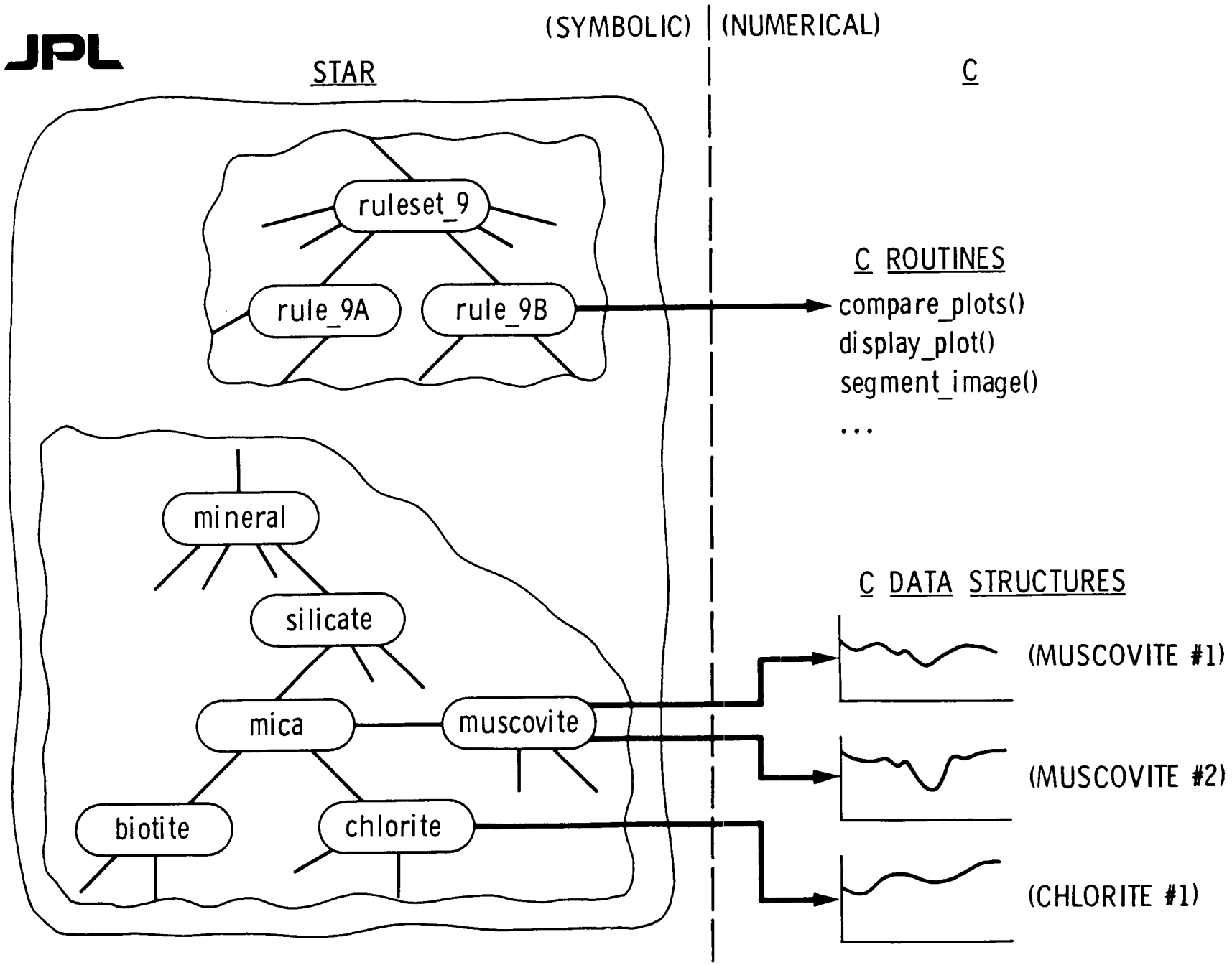


class	attribute	function	variable	element	rule
concept	name	add	i	true	rule_7f
class	member_of	if	j	false	rule_8b
attribute	...	menu	region	...	rule_23a
...		...	...	mica	...
ruleset_7				chlorite	
...				...	
material_classification					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(SYMBOLIC)
(NUMERICAL)
STAR
C
ruleset_9
rule_9A
rule_9B
C ROUTINES
compare_plots()
display_plot()
segment_image()
...
mineral
silicate
mica
muscovite
biotite
chlorite
C DATA STRUCTURES
(MUSCOVITE #1)
(MUSCOVITE #2)
(CHLORITE #1)

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A PROTOTYPE EXPERT SYSTEM

- COMPARING TRADEOFFS BETWEEN SYMBOLIC AND NUMERICAL COMPONENTS
- PROVIDING A BASIS FOR AN EVOLVING SYSTEM
- PROVIDING A FOCUS FOR INTERACTION WITH EXPERTS AND POTENTIAL USERS

PROTOTYPE EXPERT SYSTEM FOR IMAGING SPECTROMETER ANALYSIS

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(SYMBOLIC) | (NUMERICAL)

MENU DRIVEN. MENU CHANGES DYNAMICALLY AS SESSION PROGRESSES

OPTIONS
- LOAD IMAGE DATA
- DESCRIBE THE SCENE
- CALIBRATE IMAGE DATA
- SEGMENT THE IMAGE
- IDENTIFY SEGMENTED REGIONS
- DISPLAY A QUANTITY
- EXIT

RULE-BASED IDENTIFICATION OF SURFACE MATERIALS BASED ON
- VARIOUS COMPARISONS WITH PLOTS IN SPECTRAL LIBRARY
- SPATIAL ASSOCIATIONS OF SEGMENTED REGIONS
- RELATIVE NATURAL ABUNDANCE OF MATERIALS
- EXPECTATIONS OF THE USER

C ROUTINES FOR
- DISPLAY OF QUANTITIES
- IMAGE TRANSFORMATION
- DATA COMPRESSION
- COMPARISON OF SPECTRA
- SEGMENTATION OF THE IMAGE
- MIXTURE COMPONENT ANALYSIS

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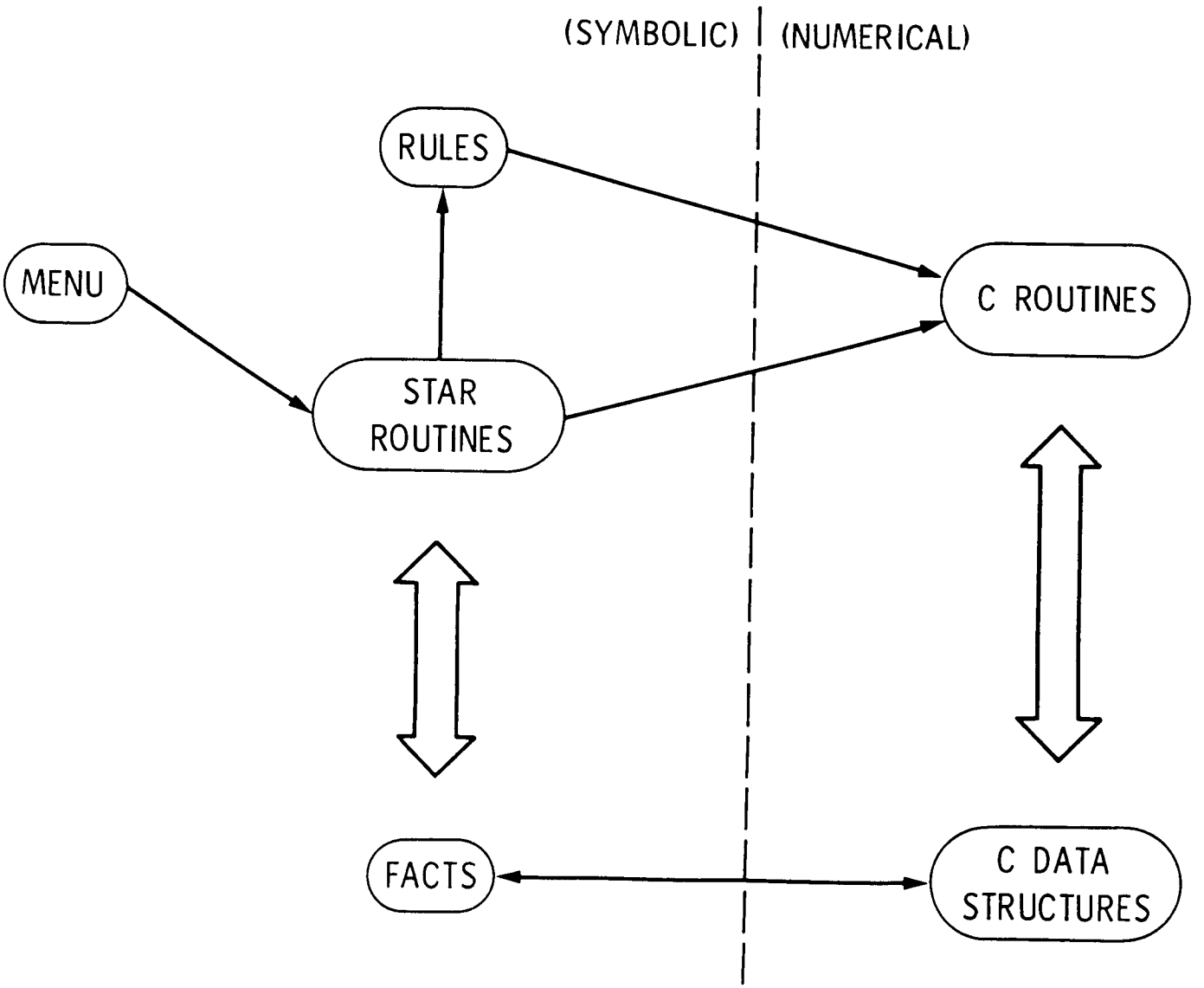
(SYMBOLIC)
(NUMERICAL)
RULES
MENU
C ROUTINES
STAR ROUTINES
FACTS
C DATA STRUCTURES

KEEPING TRACK OF MENU OPTIONS

A STEP IS ...	IF ...
ENABLED	IT MAY BE TAKEN AT THAT POINT
COMPOUNDED	TAKING IT WOULD INVALIDATE A STEP
INVALIDATED	ITS RESULTS ARE NO LONGER VALID

EXAMPLE

```
{name -> CALIBRATION_STEP
 member_of -> step
 description -> "calibrate/transform the image"
 enabled_if -> con(image_loaded master_library_loaded)
 compounded_if -> dis(image_recalibrated segmentation_completed)
 invalidated_if -> aft(image_loaded image_recalibrated)
 to_call -> calibration_step_function
 }
```

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A SAMPLE SESSION

At each prompt ("<>"), either:

1.) hit "return" to see a menu of currently available steps.

2.) enter the first word of a step as it appears in the menu.

<>

Possible steps at this point are:

-> load image and library data from files.

-> exit the session.

<> load

(... load step ...)

<>

Possible steps at this point are:

-> describe the scene and the intended analysis.

-> calibrate/transform the image.

-> segment the image into regions of similarity.

-> display a quantity.

-> backtrack to a previous step.

-> exit the session.

<> segment

(... segmentation step ...)

<>

Possible steps at this point are:

-> describe the scene and the intended analysis.
-> identify segmented regions of the image.
-> display a quantity.
-> backtrack to a previous step.
-> exit the session.

<> backtrack

Backtrack possibilities ("no" if not desired):

-> load image and library data from files.
-> calibrate/transform the image.
-> segment the image into regions of similarity.
-> no backtrack: return to main menu.

<> calibrate

(... calibration step ...)

<>

As a consequence of the backtracking just performed,
the results of the following steps are currently
invalid and have been removed from the system.
These steps may be redone if you desire:
-> segment the image into regions of similarity.

<>

Possible steps at this point are:
-> describe the scene and the intended analysis.
-> segment the image into regions of similarity.
-> display a quantity.
-> backtrack to a previous step.
-> exit the session.

<> segment
(... segmentation step...)

<>

...

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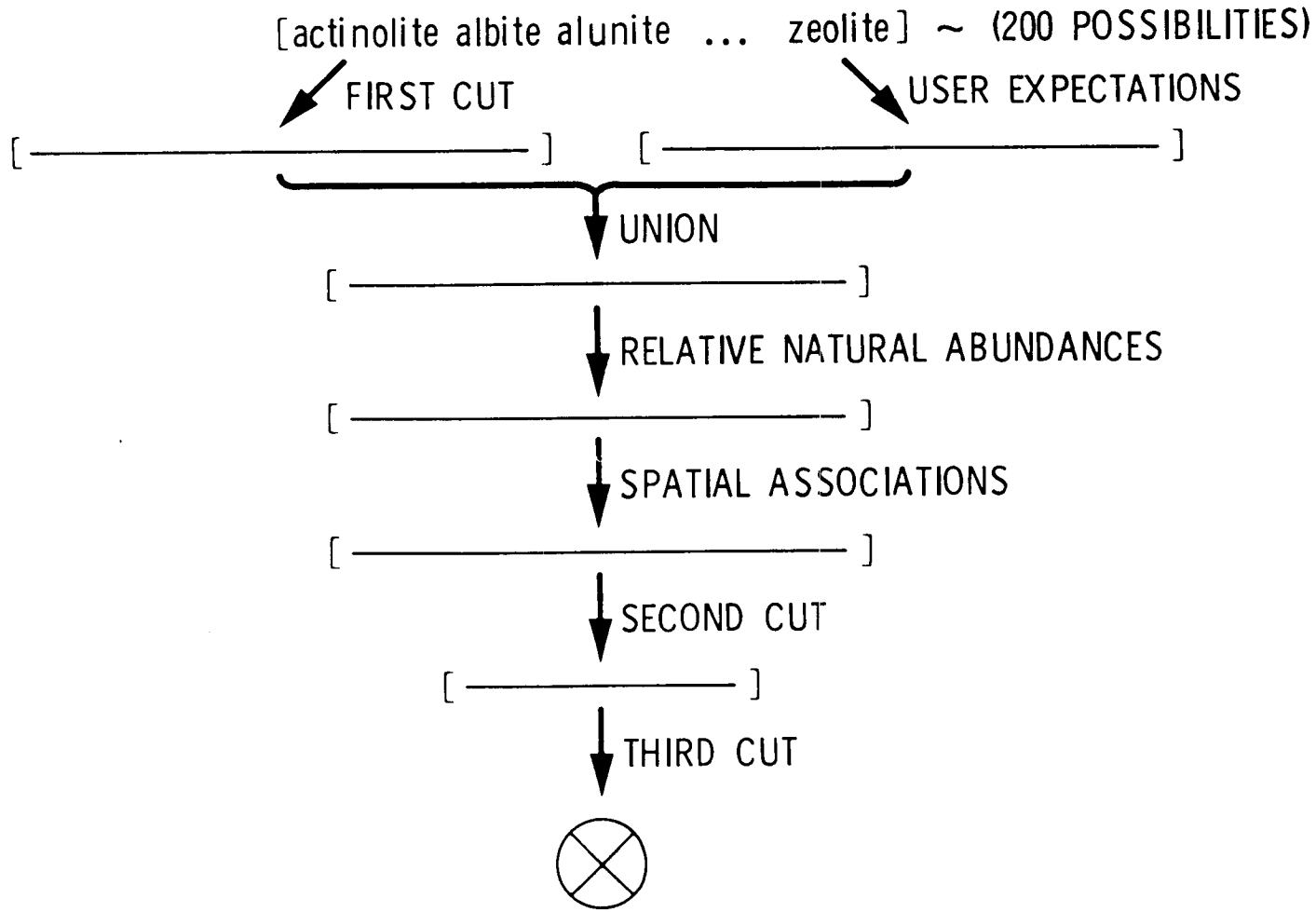
RULE-BASED IDENTIFICATION OF SURFACE MATERIALS



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EXPLANATIONS

SUPPORT FOR DOLOMITE IN REGION 4:

1) DOLOMITE WAS SELECTED AS ONE OF 63 MATERIALS HAVING ROUGHLY SIMILAR SPECTRAL CHARACTERISTICS TO THAT OF REGION 4.

2) DOLOMITE IS A RELATIVELY COMMON MINERAL.

3) NEIGHBORING REGION 5 APPEARS TO BE COMPOSED OF CALCITE WHICH IS COMMONLY FOUND IN ASSOCIATION WITH DOLOMITE.

4) A SECOND COMPARISON OPERATION DETERMINED DOLOMITE TO BE ONE OF 23 MATERIALS HAVING SIMILAR SPECTRAL CHARACTERISTICS TO THAT OF REGION 4.

5) A FINAL COMPARISON OPERATION SELECTED DOLOMITE AS ONE OF 3 MATERIALS HAVING SIMILAR SPECTRAL CHARACTERISTICS TO THAT OF REGION 4.

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- STAR EXPERT SYSTEMS TOOL COMPLETE AT THIS POINT
- MENU COORDINATION AND NUMERICAL PORTIONS OF PROTOTYPE EXPERT SYSTEM NEARLY COMPLETE
- PROJECTED OPERATIONAL STATUS OF PROTOTYPE EXPERT SYSTEM BEGINNING JUNE 85
- EXPERT SYSTEMS APPROACH IN THIS DOMAIN DOES APPEAR TO BE APPROPRIATE IN CONJUNCTION WITH TRADITIONAL NUMERICAL TECHNIQUES