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KARL: A KNOWLEDGE-ASSISTED RETRIEVAL LANGUAGE

PRESENTATION VISUALS

A Thesis
Presented to
The Graduate Faculty of
The University of Southwestern Louisiana
In Partial Fulfillment of the
Requirements for the Degree
Master of Science

Spiros Triantafyllopoulos

July 1985
OVERVIEW

INTRODUCTION
DATA RETRIEVAL
NATURAL LANGUAGE DATABASE FRONT ENDS
GENERIC DESIGN OBJECTIVES
AN INTRODUCTION TO KARL
GENERIC OBJECTIVES REVISED
DESIGN METHODOLOGY
SPECIFIC NLQS DESIGN OBJECTIVES
KARL NL PROCESSING CAPABILITIES
OVERVIEW OF THE QUERY PROCESSING CYCLE
OVERVIEW (CONT'D)

*** DATA STRUCTURES
*** LEXICAL AND GRAMMAR ANALYSIS
*** SYNTACTIC ANALYSIS
*** SEMANTIC ANALYSIS
*** FORMAL QUERY GENERATION
    AND EVALUATION
*** SYSTEM INTERCONNECTIONS
*** ANNOTATED EXAMPLES
*** EVALUATION OF OBJECTIVES
*** FUNCTIONAL EVALUATION
*** CURRENT STATUS AND FUTURE WORK
*** CONCLUSIONS
INTRODUCTION

*** APPLICABILITY OF COMPUTERS IN ALMOST EVERY HUMAN ACTIVITY

*** MORE APPLICATIONS ARE DEVELOPING

*** MORE NON-EXPERTS NEED ACCESS TO COMPUTERS

*** LACK OF COMPUTER LITERACY AMONG MANY CURRENT CASUAL USERS

*** MOST USERS EXPECT COMPUTERS WILL BE THE "SOLUTION TO ALL PROBLEMS"

*** FREQUENT USER DISSATISFACTION RESULTS

*** DEFINITE NEED FOR IMPROVED HUMAN-SYSTEM COMMUNICATIONS PROCEDURES
DATA RETRIEVAL

*** THE INFORMATION AGE IS A REALITY

*** WIDE VARIETY OF AVAILABLE TECHNOLOGIES AND SYSTEMS

*** EARLY DATA RETRIEVAL TECHNIQUES

*** SIMPLE FILE-BASED SYSTEMS

*** LARGE APPLICATION PROGRAMS

*** LACK OF MODERN CAPABILITIES

(i.e., sharing, integrity)

*** FILE MANAGEMENT SYSTEMS

*** IMPROVED PERFORMANCE

*** SOME CAPABILITIES FOR

*** SHARING

*** SECURITY

*** INTEGRITY

*** STILL, PROGRAMMING WAS NECESSARY
DATA RETRIEVAL (CONT'D)

*** DATA BASE MANAGEMENT SYSTEMS

*** SUPERIOR TO FILE MGMT. SYSTEMS

*** DIFFERENT TYPES

*** RELATIONAL

*** HIERARCHICAL

*** NETWORK

*** PROVIDE LANGUAGES FOR:

*** DATA DEFINITION/ORGANIZATION

*** DATA MANIPULATION/RETRIEVAL

*** CAPABILITIES FOR

*** SECURITY

*** DATA INDEPENDENCE

*** DATA REORGANIZATION

*** SHARING
DATA RETRIEVAL (CONT'D)

*** ACCESSING A DATABASE
   *** INTERACTIVELY
   *** BATCH MODE
   *** THRU APPLICATION PROGRAMS

*** INTERACTIVE MODE MOST FREQUENT WITH CASUAL USERS
   *** NO NEED FOR PROGRAMMING
   *** MORE CONVENIENT
   *** STILL REQUIRES FORMAL TRAINING

*** THERE IS A NEED FOR MORE EFFICIENT RETRIEVAL LANGUAGES

*** USER-ORIENTED LANGUAGES MOST APPEALING
DATA RETRIEVAL (CONT'D)

*** NATURAL LANGUAGE DATABASE QUERY SYSTEMS

*** NON-PROCEDURAL LANGUAGES

*** NO FORMAL SYNTAX OR SEMANTICS
   (SYSTEM LIMITATIONS MAY EXIST)

*** REDUCED QUERY SIZES

*** CONSIDERING CASUAL USERS:

*** MANY USERS LACK TIME OR DESIRE
   FOR FORMAL TRAINING

*** USERS LACK SYSTEM KNOWLEDGE

*** SYSTEM LACKS USER KNOWLEDGE

*** RESULTS IN "KNOWLEDGE GAP"
NL DATABASE FRONT ENDS

*** RATIONALE FOR NATURAL LANGUAGE DATABASE QUERY SYSTEMS:
INCREASED USER EFFICIENCY THROUGH IMPROVED COMMUNICATIONS BETWEEN USER AND SYSTEM

*** NL QUERIES SIMPLER THAN ANY OTHER RETRIEVAL ALTERNATIVE (FORMAL QUERIES, PROGRAMS, ETC.)

*** EXAMPLE:

FORMAL QUERY:
RANGE OF E IS EMPLOYEE
SELECT (SALARY, NAME)
WHERE (SALARY > 18,000 & SEX = "MALE")
PRINT E

NL QUERY
PLEASE PRINT THE NAMES AND SALARIES OF ALL MEN THAT EARN MORE THAN $18,000

FORMAL VERSUS NATURAL QUERY
*** MAJOR ADVANTAGES

*** INCREASED HUMAN PRODUCTIVITY

*** INCREASED SYSTEM PRODUCTIVITY
(FEWER ERRORS AND RE-TRIES)

*** REDUCED USER FRUSTRATION

*** VIRTUAL ELIMINATION OF A TRAINING PERIOD

*** CUSTOMIZED CAPABILITIES CAN BE PROVIDED

*** IMPROVED HANDLING OF "NATURAL" LANGUAGE CONCEPTS
(THESAURUS, SYNONYMS, ETC)

*** POSSIBLE INTEGRATION INTO A TOTAL NL FRONT END ENVIRONMENT
NL DATABASE FRONT ENDS (CONT'D)

*** PROBLEMS WITH NL IMPLEMENTATIONS ON EXISTING SYSTEMS

*** LONG DEVELOPMENT TIMES

*** RESTRICTED APPLICATION DOMAINS

*** POOR PORTABILITY BETWEEN OPERATING SYSTEMS/TOOLS

*** SOME SYSTEMS DO NOT SUPPORT PRODUCTION LEVEL DBMS'S

*** EXTENSIVE RESOURCE UTILIZATION

*** STILL, EXISTING NLQS'S ARE IN HIGH DEMAND BY USERS AT ALL LEVELS

*** MANY PRODUCTION MODELS AVAILABLE
GENERIC DESIGN OBJECTIVES

*** ADAPTABILITY TO NEW APPLICATIONS

*** SYSTEM MUST BE USABLE WITH NO CODE MODIFICATIONS

*** PORTABILITY BETWEEN DATABASE SYSTEMS AND OPERATING SYSTEMS

*** REDUCED COMPLEXITY

*** MODULAR, INDEPENDENT DESIGN

*** SIMPLE IMPLEMENTATION

*** EFFICIENCY

*** OPTIMIZED DESIGN

*** OPTIMIZED IMPLEMENTATION
AN INTRODUCTION TO KARL

*** KARL IS A:

KNOWLEDGE

ASSISTED

RETRIEVAL

LANGUAGE

*** RESTRICTED NATURAL LANGUAGE
DATABASE QUERY SYSTEM

*** KNOWLEDGE-ASSISTED
(OTHER TECHNIQUES ALSO USED)

*** EXPERIMENTAL VEHICLE
FOR THE DESIGN AND IMPLEMENTATION
OF NATURAL LANGUAGE QUERY SYSTEMS
GENERIC DESIGN OBJECTIVES REVISED

*** ADAPTABILITY

*** KNOWLEDGE BASE CAN BE REDEFINED TO USE WITH NEW APPLICATIONS

*** LANGUAGE-RELATED KNOWLEDGE
(LANGUAGE RULES ARE TYPICALLY INDEPENDENT OF APPLICATION)

*** PORTABILITY

*** KARL IS IMPLEMENTED USING:

*** "C" PROGRAMMING LANGUAGE

*** UNIX 4.2 OPERATING SYSTEM

*** INGRES V7 DBMS

*** NO SYSTEM-DEPENDENT CALLS

*** GENERAL EMBEDDED QUERY STRUCTURE
*** REDUCED COMPLEXITY

*** COMMON PROGRAMMING LANGUAGE USED

*** HIGHLY MODULAR DESIGN

*** PRECISE MODULE INTERFACES

*** SINGLE-FUNCTION COMPONENTS

*** EFFICIENCY

*** NO DYNAMIC MEMORY ALLOCATION

*** SIMPLE, EFFICIENT ALGORITHMS

*** USE OF A COMPILED LANGUAGE

*** REDUCED SUBROUTINE CALLS

*** FURTHER OPTIMIZATION POSSIBLE
DESIGN METHODOLOGY

*** DIVIDE-AND-CONQUER APPROACH

*** DIVIDES TASK OF NL PROCESSING INTO A SEQUENCE OF SUB-PROBLEMS

*** DEFINES PRECISE INTEGRATION

*** SOLVES INDIVIDUAL PROBLEMS

*** INTEGRATES INTO FUNCTIONAL SYSTEM

*** FUNCTIONAL DECOMPOSITION

*** EACH MODULE PERFORMS A SINGLE TASK

*** MODULE SIZE DEPENDS ON FUNCTION

*** USES SOFTWARE TOOLS WHERE POSSIBLE
**DESIGN METHODOLOGY (CONT'D)**

*** TOP-DOWN INTEGRATION IS USED

*** CONVENIENCE OF UPDATES/IMPROVEMENTS

*** EFFICIENT DESIGN

*** ERRORS ISOLATED IN SINGLE MODULES

*** INTEGRATION PROCEDURE

*** COMMON QUERY REPRESENTATION AMONG DIFFERENT MODULES

*** EACH MODULE IS VIEWED AS A "BLACK BOX"

*** SEQUENTIAL PROCESSING ORGANIZATION

*** PROVISION IS MADE FOR ERROR SIGNALS
SPECIFIC NLOS OBJECTIVES

*** KNOWLEDGE STORAGE, RETRIEVAL, ACQUISITION AND UTILIZATION CAPABILITIES

*** GRAMMATICAL AND LEXICAL CONSTRUCTS HANDLING CAPABILITIES

*** SYNTACTIC HANDLING CAPABILITIES

*** SEMANTIC HANDLING CAPABILITIES

*** ELLIPTIC QUERY HANDLING AND GENERAL ERROR REPORTING CAPABILITIES
KARL NL PROCESSING CAPABILITIES

*** KNOWLEDGE CAPABILITIES

*** KNOWLEDGE ACQUISITION

*** AT DEVELOPMENT TIME

*** AT SETUP TIME

*** DURING ACTUAL USE

*** KNOWLEDGE REPRESENTATION

*** FRAME-BASED DYNAMIC KNOWLEDGE

*** RULE-BASED STATIC KNOWLEDGE

*** KNOWLEDGE UTILIZATION

*** IN ALL ASPECTS OF QUERY PROCESSING

*** EMBEDDED IN MODULES
KARL NL PROCESSING CAPABILITIES (CONT'D)

*** GRAMMAR/LEXICAL ANALYSIS CAPABILITIES

*** DETERMINES WORD TYPES
*** PERFORMS QUERY "CLEAN-UP"
*** GENERATES DATA STRUCTURES

*** SYNTACTIC VERIFICATION CAPABILITIES

*** OPERATES ON SINGLE DATA STRUCTURE
*** A VARIATION OF NETWORK GRAMMARS
   IS USED (RECURSIVE TRANSITION GRAMMARS)
*** DIFFERENT RIN FAMILIES HANDLED
*** APPLICATION-INDEPENDENT
   PROCEDURE IS USED
*** CAPABLE OF RESOLVING AMBIGUITIES
KARL NL PROCESSING CAPABILITIES

*** SEMANTIC VERIFICATION

*** LINGUISTIC SEMANTICS

*** NOUN/VERB PHRASES

*** ADJECTIVE HANDLING

*** ELLIPSIS/AMBIGUITY HANDLING

*** DB VERIFICATION

*** QUERY SEMANTICS

*** INTEGRITY CONSTRAINTS

*** LEARNING CAPABILITIES

*** UPDATE APPLICATION KNOWLEDGE

*** PROVIDE CUSTOMIZED PROCESSING

*** ELLIPSIS AND AMBIGUITY CAPABILITIES

*** MISSING TERMS

*** USER CAN SUPPLY MISSING PARTS
OVERVIEW OF THE QUERY PROCESSING CYCLE

*** LEXICAL/GRAMMAR ANALYSIS

*** IDENTIFY TOKENS/TYPES

*** REPLACE SYNONYMS/REMOVE NOISEWORDS

*** GENERATE DATA STRUCTURES

*** SYNTACTIC ANALYSIS AND VERIFICATION

*** SUBMIT TOKEN TYPE LIST TO VERIFIER

*** RECEIVE PATTERN FAMILY IDENTIFIER OR ERROR CODE (IF ERROR)

*** USE PATTERN IDENTIFIER FOR FURTHER QUERY PROCESSING
OVERVIEW OF THE QUERY PROCESSING CYCLE (CONT'D)

*** SEMANTIC VERIFICATION

*** VERIFY LINGUISTIC SEMANTIC CORRECTNESS
*** VERIFY DATABASE SEMANTIC CORRECTNESS
*** RESOLVE AMBIGUITIES/ELLIPSES

*** FORMAL QUERY GENERATION

*** TRANSFORM TOKEN AND IDENTIFIER LISTS INTO GENERIC QUERY FORMAT
*** GENERATE HOST DBMS QUERY

*** FORMAL QUERY EVALUATION

*** OPEN DATABASE
*** EXECUTE QUERY
*** CLOSE DATABASE
AN OVERVIEW OF THE QUERY PROCESSING CYCLE (CONT'D)

Input Query

LEXICAL ANALYSIS

SYNTAX VERIFIER

SEMANTIC VERIFIER

FORMAL QUERY GENERATION

FORMAL QUERY EVALUATION

Intelligent Dictionary Grammar Knowledge

Syntax Knowledge

Schema Knowledge

Semantic Knowledge

Schema Knowledge

Schema Knowledge

Formal Syntax Knowledge

Formal Semantic Knowledge

Formal Syntax Knowledge

Formal Semantic Knowledge

DBMS Specific Knowledge

THE NL QUERY PROCESSING CYCLE
DATA STRUCTURES

*** NL QUERY: LINKED LISTS

*** TOKEN LIST

*** TOKEN IDENTIFIER LIST

<table>
<thead>
<tr>
<th>NO.</th>
<th>token</th>
<th>_</th>
<th>NO.</th>
<th>type</th>
<th>_</th>
</tr>
</thead>
<tbody>
<tr>
<td>_</td>
<td>_</td>
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<td>_</td>
<td></td>
</tr>
</tbody>
</table>

STRUCTURE OF NL QUERY STORAGE AREA
DATA STRUCTURES (CONT'D)

*** SAMPLE TOKENS AND TOKEN IDENTIFIERS:

<table>
<thead>
<tr>
<th>FORMAL QUERY</th>
<th>FORMAL QUERY (with no noicewords)</th>
<th>TOKEN PATTERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>print all students taking &quot;CMPS351&quot; and living in &quot;Lafayette&quot;</td>
<td>print student enroll &quot;CMPS351&quot; &amp; live &quot;Lafayette&quot;</td>
<td>Verb Noun Verb Literal Boolean Verb Literal</td>
</tr>
</tbody>
</table>

*** LINKED LIST BASED IMPLEMENTATION
DATA STRUCTURES (CONT'D)

*** DICTIONARY
CONTAINS LIST OF ALL KNOWN WORDS AND TYPES

*** NOUN TABLE
CONTAINS LIST OF ALL KNOWN NOUNS, EITHER
RELATION NAMES OR ATTRIBUTES

*** SYNONYMS TABLE
CONTAINS SYNONYMS AND EQUIVALENT TERMS

*** VERBS TABLE
CONTAINS VERBS AND RELATED NOUNS

*** ADJECTIVES TABLE
CONTAINS ADJECTIVES AND ASSOCIATED
PROPERTIES ASSIGNED TO NOUNS

*** MULTIPLE SEQUENCE PATTERNS TABLE
CONTAINS NOUN SEQUENCES MAPPED TO
SINGLE NOUNS IN THE KNOWLEDGE BASE
DATA STRUCTURES (CONT'D)

Noun Frame

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Datatype</th>
<th>Max</th>
<th>Min</th>
<th>Pattern</th>
<th>Unit</th>
</tr>
</thead>
</table>

Synonyms Representation

<table>
<thead>
<tr>
<th>term</th>
<th>stands for</th>
</tr>
</thead>
</table>

Verbs Representation

<table>
<thead>
<tr>
<th>verb</th>
<th>subject</th>
<th>object</th>
</tr>
</thead>
</table>

Adjective Representation

<table>
<thead>
<tr>
<th>Adjective</th>
<th>Noun</th>
<th>Implied_property</th>
</tr>
</thead>
</table>

Dictionary Representation

<table>
<thead>
<tr>
<th>Word</th>
<th>Word_type</th>
</tr>
</thead>
</table>

Multiword Representation

<table>
<thead>
<tr>
<th>Term</th>
<th>Pattern_id</th>
<th>Rank</th>
</tr>
</thead>
</table>

DYNAMIC KNOWLEDGE REPRESENTATION SCHEMA
LEXICAL AND GRAMMAR ANALYSIS

*** LEXICAL ANALYSIS

*** IDENTIFY TOKENS

*** ATTACH TOKEN IDENTIFIERS

*** GRAMMAR TRANSFORMATIONS MAY BE NEEDED

*** REPLACE SYNONYMS/REMOVE NOISEWORDS

---
Read NL Query

---
Replace Multiple Sequence Patterns

---
Generate Tokens

---
Replace Synonyms and Noisewords

---

LEXICAL ANALYSIS OF INPUT NL QUERY
LEXICAL AND GRAMMAR ANALYSIS (CONT'D)

*** GRAMMAR ANALYSIS

*** IF WORD IS KNOWN, THEN PROCEED

*** USE RULES TO DETERMINE WORD TYPE

*** QUERY USER IF UNKNOWN

*** RULES ENCODED AS "C" FUNCTIONS

---

GRAMMAR ANALYSIS OF INPUT QUERY
SYNTACTIC ANALYSIS

... VERIFIES CORRECTNESS OF NL QUERY BASED ON SYNTACTIC CRITERIA

... MEANING OF ENTITIES NOT CONSIDERED

... NETWORK-BASED GRAMMAR

... TOKEN TYPES CURRENTLY SUPPORTED:

... NOUNS (N)
... ADJECTIVES (A)
... BOOLEAN OPERATORS (B)
... RELATIONAL OPERATORS (R)
... SYNONYMS (S)
... VERBS (V)
... LITERALS (L)
SYNTACTIC ANALYSIS (CONT'D)

*** TOKEN SEQUENCES ( PATTERNS )
*** VERIFY RELATIVE POSITION OF TOKENS
*** DIFFERENT PATTERN FAMILIES REPRESENTED
*** EXAMPLE:

V (NB?)+ (VLB?)+ print names of students 
that live in "Dallas"

V (NB?)+ (NR+LB?)+ print names of faculty 
with salary of more than 24,000

V (AN)+ print the good students

V (VLB?) who is working in "Dallas"?
{"who" is replaced by 
retrieve name"}

( a ) repetitions of construct "a"

a+ one or more occurrences of construct "a"

a? construct "a" is optional

a* zero or more occurrences of construct "a"

SAMPLE PATTERNS AND QUERIES
SYNTACTIC ANALYSIS (CONT'D)

*** IMPLEMENTS RNA VERIFIER USING A
 FINITE STATE AUTOMATON REGULAR
 EXPRESSION RECOGNIZER

*** ACCEPT/REJECT STATES ONLY

*** 11 PATTERN FAMILIES SUPPORTED

*** IF NO PATTERN MATCHES, QUERY IS REJECTED

*** FINITE STATE AUTOMATON IMPLEMENTED
 THROUGH THE "LEX" LEXICAL ANALYZER
 GENERATOR SOFTWARE TOOL

*** "LEX" ACCEPTS FINITE STATE AUTOMATA
 SPECIFICATIONS AND GENERATES SOURCE
 CODE FOR REGULAR EXPRESSION VERIFIERS
 BASED ON THE SPECIFICATIONS
SYNTACTIC ANALYSIS (CONT'D)

*** "LEX" DESCRIPTION FOR SAMPLE RECOGNIZER:

```
[A-Za-z][A-Za-z0-9_]'   | return (IS_VARIABLE);
-?[0-9]+               | return (IS_INTEGER);
"[0-9\.]\+            | return (IS_FLOATING);
"+"/%'                 | return (IS_OPERATOR);
```

*** "LEX" CONSTRUCTS

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Z</td>
<td>matches single character uppercase</td>
</tr>
<tr>
<td>a-z</td>
<td>matches single character lowercase</td>
</tr>
<tr>
<td>0-9</td>
<td>matches single digit</td>
</tr>
<tr>
<td>[...]</td>
<td>groups sub-patterns</td>
</tr>
<tr>
<td>.</td>
<td>any character</td>
</tr>
<tr>
<td>*</td>
<td>zero or more times repetition</td>
</tr>
<tr>
<td>+</td>
<td>one or more times repetition</td>
</tr>
<tr>
<td>$</td>
<td>indicates end of line</td>
</tr>
<tr>
<td>?</td>
<td>optional element</td>
</tr>
</tbody>
</table>

SAMPLE LEX RECOGNIZER AND LEX CONSTRUCTS
**SEMANTIC ANALYSIS**

*** LINGUISTIC ANALYSIS

*** NOUN PHRASE VERIFICATION

*** VERB PHRASE VERIFICATION

*** AMBIGUITY RESOLVING

*** ELLIPSIS/PLETHORA HANDLING

*** PROCESS FLOW DIAGRAM:

```
+---+  +---+  +---+
| Token Flow | Ellipsis | Plethora | Ambiguity |
+---+  +---+  +---+
| V +---+  +---+  +---+
```
SEMANTIC ANALYSIS (CONT'D)

*** DB VERIFICATION

*** LITERAL RANGES

*** LITERAL PATTERNS

*** OPERATORS

*** OTHER INTEGRITY CONSTRAINTS

*** IS-A MATCHES (RELATIONSHIP MEMBERSHIP)

*** PROCESS FLOW DIAGRAM:

Token Flow

| Literal Ranges | Literal Patterns | Operator Check | Is-A Matches |

Operand Concordance

V
SEMPANIC ANALYSIS (CONT'D)

*** IMPLEMENTED THROUGH "C" FUNCTIONS

*** USES DYNAMIC KNOWLEDGE

*** BOTH RULE- AND FRAME- BASED

*** SAMPLE RULES:

IF TOKEN(N) IS ADJECTIVE
THEN TOKEN(N + 1) MUST BE NOUN AND
NOUN AND ADJECTIVE MUST AGREE
AND HAVE ENTRY IN THE KB-ADJ.
ELSE ERROR = NO-NOUN-ADJ-AGREEMENT.

IF TOKEN(N) IS VERB
THEN TOKEN(N-K), TOKEN(N+K) ARE NOUNS
AND MUST AGREE WITH THE DEFINITION OF THE VERB IN THE KB-VERB.
ELSE ERROR = NO-VERB-NOUN-AGREEMENT.

IF TOKEN(N) IS LITERAL
THEN TOKEN(N-K) IS THE NOUN ENTITY
SO VERIFY THAT LITERAL RANGE
IS ACCEPTABLE
ELSE ERROR = LIT-OUT-OF-RANGE.

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FORMAL QUERY GENERATION AND EVALUATION

*** RELATIVELY SIMPLE TASK AS NL QUERY IS BEING "FORMALIZED" THROUGHOUT THE PROCESS CYCLE

*** DETERMINES DOMAINS/RANGES OF ATTRIBUTES
*** DETERMINE TYPE OF OPERATION REQUESTED (COUNT, EXIST, RETRIEVE, ETC.)

*** SELECT ATTRIBUTES TO BE RETRIEVED

*** STRUCTURE THE CONDITIONALS LIST TO CONFORM WITH "SELECT-FROM-WHERE" GENERIC QUERY FORMAT

*** CREATE GENERIC "SELECT-FROM-WHERE" QUERY AND DISPLAY IT TO THE USER
FORMAL QUERY GENERATION AND EVALUATION (CONT'D)

*** VERIFY GENERIC QUERY FOR CORRECTNESS (I.E., BOOLEAN OPERATORS MAY BE MISSING)

*** GENERATE HOST DBMS-SPECIFIC FORMAL QUERY

*** EXECUTE HOST DBMS-SPECIFIC QUERY

*** DISPLAY RESULTS TO THE USER

*** GENERIC AND INGRES QUERY FORMATS:

"Blank" Format:

SELECT <attribute_list>
FROM <domain>
WHERE <condition_list>

QUEL Format:

RANGE OF <abbrev_name> IS <domain>
RETRIEVE <dot_attr_list>
WHERE <dot_conditional_list>
(dot is the attribute domain prefix indicator)
INTERNAL MODULE CONNECTIONS:

Input NL Query

- Lexical and Grammar Analysis

- Syntax Analysis and Verification

---

Knowledge Base Mgmt System

- Semantic Analysis and Verification

- Query Generation

- Query Evaluation

---

Error Handling
SYSTEM INTERCONNECTIONS (CONT'D)

*** EXTERNAL SYSTEM CONNECTIONS

UNIX

The KARL System

INGRES Relational DBMS

low level

data base
data base

Knowledge Base

high level

(All Data Paths Bi-Directional)
ANNOTATED EXAMPLES

QUERY 1:
show the students enrolled in "CMPS351" or "CMPS360"

LEXICAL ANALYSIS: show student enroll "CMPS351" or "CMPS360"

(ellipsis): show student enroll "CMPS351" or enroll "CMPS360"

PATTERN: Verb (Noun Bool?) (Verb Literal Bool?)

SYNTACTIC ANALYSIS: Pattern Accepted, Pattern_No = 8

SEMANTIC ANALYSIS: enroll (student, course)

  course PATTERN = "XXXX9999"
  course Number = 360 < 699

  course Number = 351 < 699

BLANK QUERY:
SELECT all /* default */
FROM student
WHERE (course = "CMPS351" | course = "CMPS360")

QUERY PROCESSED CORRECTLY
QUERY 2:

who is "000-4076-65"

LEXICAL ANALYSIS: retrieve name "000-4076-65" (severe ellipsis): retrieve name "000-4076-65"

PATTERN: Verb ( Noun Rel_op? Literal Bool? )+

SYNTACTIC ANALYSIS: Pattern Accepted, Pattern_No = 4

SEMANTIC ANALYSIS: Pattern "999-9999-999" matches ssn

REFORMS: show student ssn "000-4076-65"

ssn PATERN = "999-9999-99"

BLANK QUERY: SELECT name FROM student WHERE (ssn = "000-4076-65")

QUERY PROCESSED CORRECTLY
QUERY 3:
print names and addresses of all the rich faculty

LEXICAL ANALYSIS: print name address rich faculty

PATTERN: Verb (Noun Bool?)+ ( Adjective Noun )+

SYNTACTIC ANALYSIS: Pattern Accepted, Pattern No = 12

SEMANTIC ANALYSIS: name belongs to faculty
address belongs to faculty
rich := salary > 40,000

REFORMS: print name address faculty
salary > 40,000
salary range acceptable

BLANK QUERY

SELECT name, address
FROM faculty
WHERE salary > 40000

QUERY ACCEPTED
QUERY 4:
show students who live and work in "Lafayette"

LEXICAL ANALYSIS: show student live & work "Lafayette"

PATTERN MATCHED: NONE (although sentence is correct)

SYNTACTIC ANALYSIS: Failed. Program could not parse input sentence (No double verb pattern supported)

QUERY REJECTED
QUERY 5:
show the rich students

LEXICAL ANALYSIS: show rich student

PATTERN MATCHED: Verb ( Noun Relop Literal Bool?)+
(severe ellipsis, matches after replacing "rich")

SYNTACTIC ANALYSIS: Pattern valid. Pattern No: 4

SEMANTIC ANALYSIS: rich student: error.
Attribute "salary" not associated
with relation "student"

QUERY REJECTED
QUERY 6:
show the students enrolled in "CMPS999"

LEXICAL ANALYSIS: show student enroll "CMPS999"

PATTERN MATCHED: Verb ( Verb Literal Bool? )+

SYNTACTIC ANALYSIS: Pattern valid. Pattern No: -11

SEMANTIC ANALYSIS: enroll ( student, class ) OK
class pattern OK
class number out of range
class number > 699

QUERY REJECTED
EVALUATION OF OBJECTIVES

*** DETERMINE IF GENERIC AND SPECIFIC OBJECTIVES HAVE BEEN MET WITH THE PROPOSED DESIGN

*** GENERIC OBJECTIVES:

*** ADAPTABILITY

*** PORTABILITY

*** REDUCED COMPLEXITY

*** EFFICIENCY

*** GENERIC OBJECTIVES HAVE BEEN MET THROUGH METHODOLOGY PRESENTED
EVALUATION OF OBJECTIVES (CONT'D)

III SPECIFIC DESIGN OBJECTIVES

*** KNOWLEDGE STORAGE, RETRIEVAL, ACQUISITION AND UTILIZATION CAPABILITIES

*** GRAMMATICAL AND LEXICAL CONSTRUCTS HANDLING CAPABILITIES

*** SYNTACTIC HANDLING CAPABILITIES

*** SEMANTIC HANDLING CAPABILITIES

*** ELLIPTIC QUERY HANDLING AND GENERAL ERROR REPORTING CAPABILITIES

*** SPECIFIC DESIGN OBJECTIVES HAVE ALSO BEEN MET THROUGH FOLLOWING THE GUIDELINES SET BY THE GENERIC DESIGN CRITERIA AND THE DESIGN METHODOLOGY PRESENTED

*** KARL 1.00 CAPABLE OF PROCESSING 60-65% OF QUERIES SUBMITTED (ADJUSTED FOR TYPING AND SPELLING ERRORS).
FUNCTIONAL EVALUATION

CRITERION

<table>
<thead>
<tr>
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<th>KARL</th>
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<tbody>
<tr>
<td>1.</td>
<td>Be able to access multiple databases (i.e., retargetable within applications)</td>
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<tr>
<td>2.</td>
<td>Answer questions asked directly (i.e., Who)</td>
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<td>3.</td>
<td>Handle multiple files and relationships</td>
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<td>4.</td>
<td>Handle simple pronoun references</td>
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<td>5.</td>
<td>Be able to handle ellipsis</td>
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<td>6.</td>
<td>Provide report generating facilities for the retrieved data (i.e., formats, graphs, etc)</td>
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<td>7.</td>
<td>Be able to extend the linguistic knowledge of the system during program execution</td>
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<td>8.</td>
<td>Handle null cases, indicating the condition(s) that failed</td>
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<tr>
<td>9.</td>
<td>Restate in English the user's query</td>
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<tr>
<td>10.</td>
<td>Handle spelling and typing errors</td>
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<tr>
<td>11.</td>
<td>Provide special functions for improvement of the database capabilities</td>
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<tr>
<td>12.</td>
<td>Provide semantic constraints in the dialogue between the human and the machine, and handle errors such as plethora and ambiguity</td>
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(a) Item has been considered as future extension
(b) Item not in the original design considerations
(c) The program restates the semi-formally
CURRENT STATUS AND FUTURE WORK

*** CURRENT LIMITATIONS:

*** NESTED QUERIES

*** SPELLING CORRECTION

*** NULL QUERY HANDLING

*** PRONOUN REFERENCES

*** DYNAMIC KNOWLEDGE BASE STATUS:
255 TOTAL KNOWN WORDS
  8 VERBS
  7 ADJECTIVES
20 FRAMES
27 MULTIPLE SEQUENCES
24 NOUNS
45 SYNONYMS

*** CURRENT APPLICATION: UNIVERSITY DATABASE
CURRENT STATUS AND FUTURE WORK (CONT'D)

*** FUTURE RESEARCH TOPICS:

*** NESTED QUERY HANDLING

*** PRONOUN REFERENCES

*** SPELLING CORRECTION

*** NULL QUERY HANDLING

*** INTERFACE WITH OTHER SYSTEMS
  (I.E., COMMON COMMAND LANGUAGE IS&R FRONT END, OFFICE AUTOMATION SYSTEMS, OR OTHERS)

*** QUERY OPTIMIZATION
CONCLUSIONS

*** SIGNIFICANCE OF THE THESIS:

*** AN ALTERNATE DESIGN METHODOLOGY FOR NLPS WAS INTRODUCED

*** DESIGN CONSIDERATIONS AND METHODOLOGY APPLICABLE TO OTHER NL PROCESSING AREAS

*** A FOUNDATION FOR FURTHER RESEARCH AND DEVELOPMENT WAS PRESENTED

*** FURTHER RESEARCH TOPICS WERE IDENTIFIED

*** SOLUTIONS WERE PROPOSED FOR SUCH TOPICS USING CURRENT PROTOTYPE AS A FOUNDATION
CONCLUSIONS (CONT'D)

*** NO NEED TO EMULATE OR SIMULATE NATURE

*** AN INVENTING RATHER THAN AN IMITATING APPROACH IS NEEDED

*** FUNCTIONAL EQUIVALENCE CAN OBTAIN SIMILAR RESULTS WITH SIMULATION/EMULATION, USING CONVENTIONAL TOOLS AND TECHNIQUES

*** FUNCTIONAL DECOMPOSITION CAN ASSIST IN REDUCING COMPLEX PROBLEMS INTO WORKABLE SIZE PROBLEMS

*** TECHNIQUES EXIST FOR SOLVING SMALLER SIZE PROBLEMS (COMPILER METHODS, SOFTWARE TOOLS, ARTIFICIAL INTELLIGENCE, ETC.)
CONCLUSIONS (CONT'D)

*** A NLQS CAN PROVIDE THE FOUNDATION FOR OTHER NL-BASED SOFTWARE SYSTEMS

*** DEFINED FUNCTIONALITY OF EACH COMPONENT WILL BE REQUIRED WITH NO INTERDEPENDENCIES

*** INTEGRATION TECHNIQUES WILL HAVE TO BE DEVELOPED TO MERGE ALL NL-BASED COMPONENTS INTO AN INTEGRATED ENVIRONMENT

*** THEN, THE "HUMAN COMPUTER" PROBLEM CAN BE ADDRESSED AND SOLUTIONS PRESENTED

This report represents one of the 72 attachment reports to the University of Southwestern Louisiana's Final Report on NASA Grant NGT-19-010-900. Accordingly, appropriate care should be taken in using this report out of the context of the full Final Report.

Key Words (Suggested by Author(s))

KARL, Knowledge-Assisted Retrieval Language, Information Storage and Retrieval Systems