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(54) COMPUTER-IMPLEMENTED MULTI-SCANNING LANGUAGE METHOD AND SYSTEM

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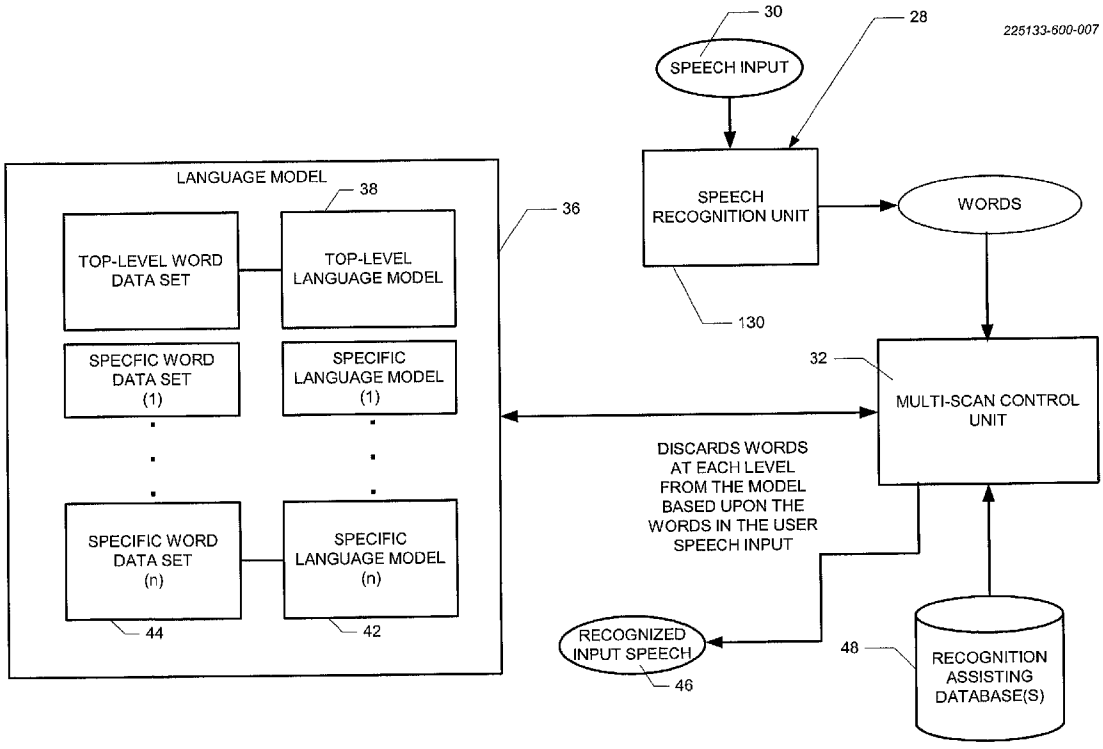
(57) **ABSTRACT**

A computer-implemented method and system for speech recognition of a user speech input. The user speech input which contains utterances from a user is received. A first language model recognizes at least a portion of the utterances from the user speech input. The first language model has utterance terms that form a general category. A second language model is selected based upon the identified utterances from use of the first language model. The second language model contains utterance terms that are a subset category of the general category of utterance terms in the first language model. Subset utterances are recognized with the selected second language model from the user speech input.



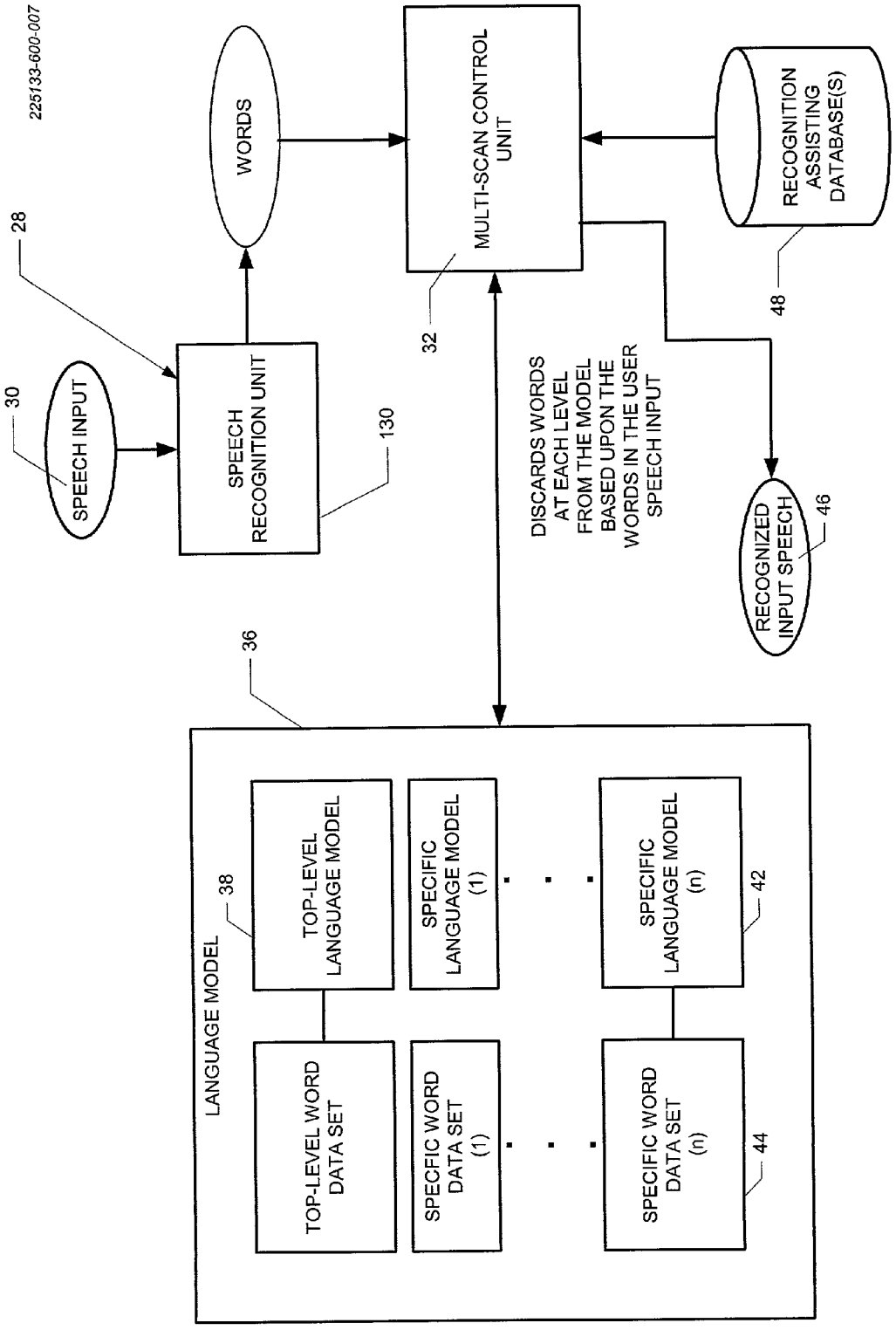

225133-600-007
28
30
SPEECH INPUT
SPEECH RECOGNITION UNIT
130
WORDS
MULTI-SCAN CONTROL UNIT
32
RECOGNITION ASSISTING DATABASE(S)
48
DISCARDS WORDS AT EACH LEVEL FROM THE MODEL BASED UPON THE WORDS IN THE USER SPEECH INPUT
RECOGNIZED INPUT SPEECH
46
36
LANGUAGE MODEL
38
TOP-LEVEL LANGUAGE MODEL
SPECIFIC LANGUAGE MODEL (1)
SPECIFIC LANGUAGE MODEL (n)
42
TOP-LEVEL WORD DATA SET
SPECFIC WORD DATA SET (1)
SPECIFIC WORD DATA SET (n)
44

FIG. 1

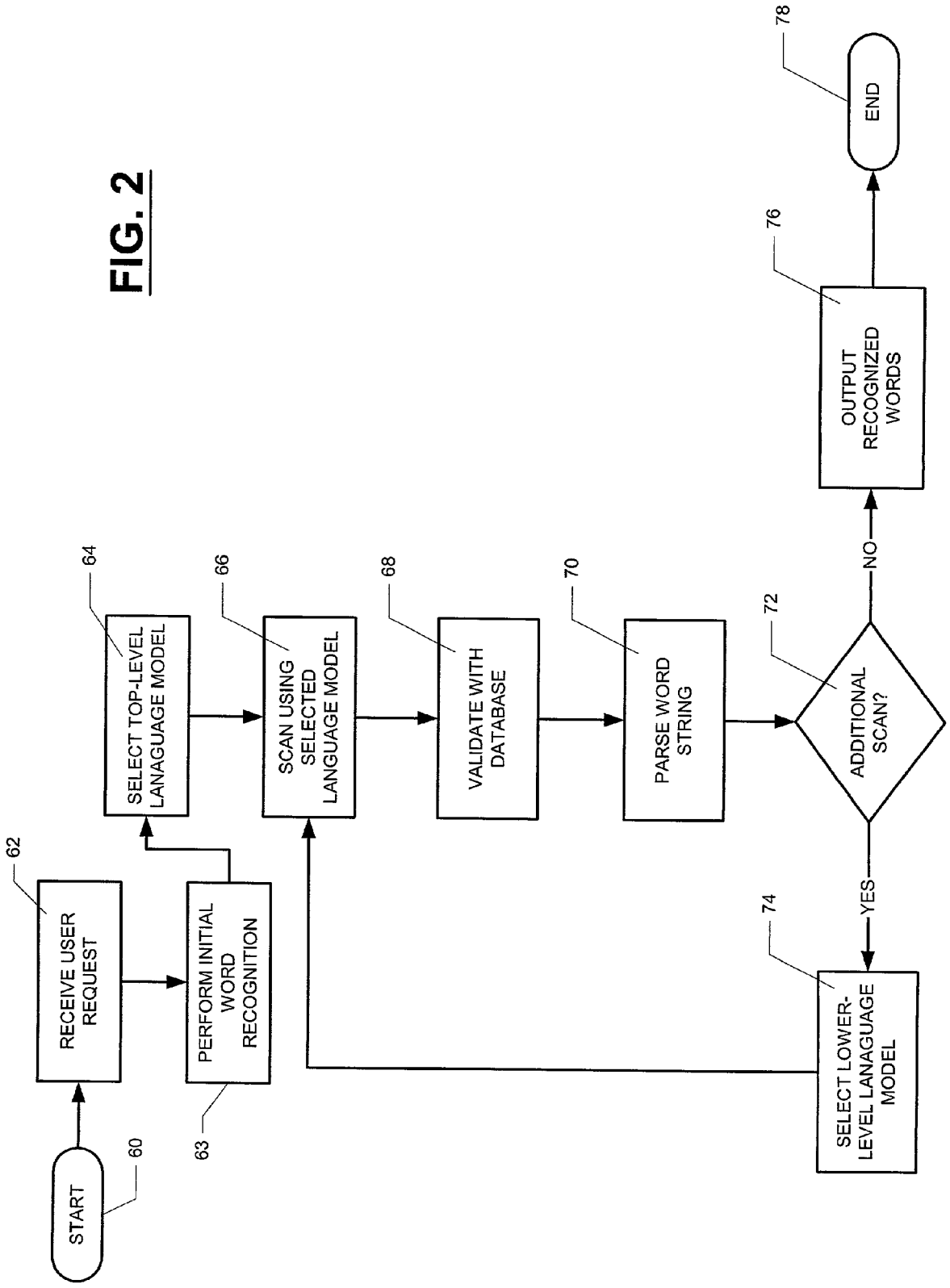

START
60
RECEIVE USER REQUEST
62
PERFORM INITIAL WORD RECOGNITION
63
SELECT TOP-LEVEL LANAGUAGE MODEL
64
SCAN USING SELECTED LANGUAGE MODEL
66
VALIDATE WITH DATABASE
68
PARSE WORD STRING
70
ADDITIONAL SCAN?
72
YES
NO
SELECT LOWER-LEVEL LANAGUAGE MODEL
74
OUTPUT RECOGNIZED WORDS
76
END
78

FIG. 2

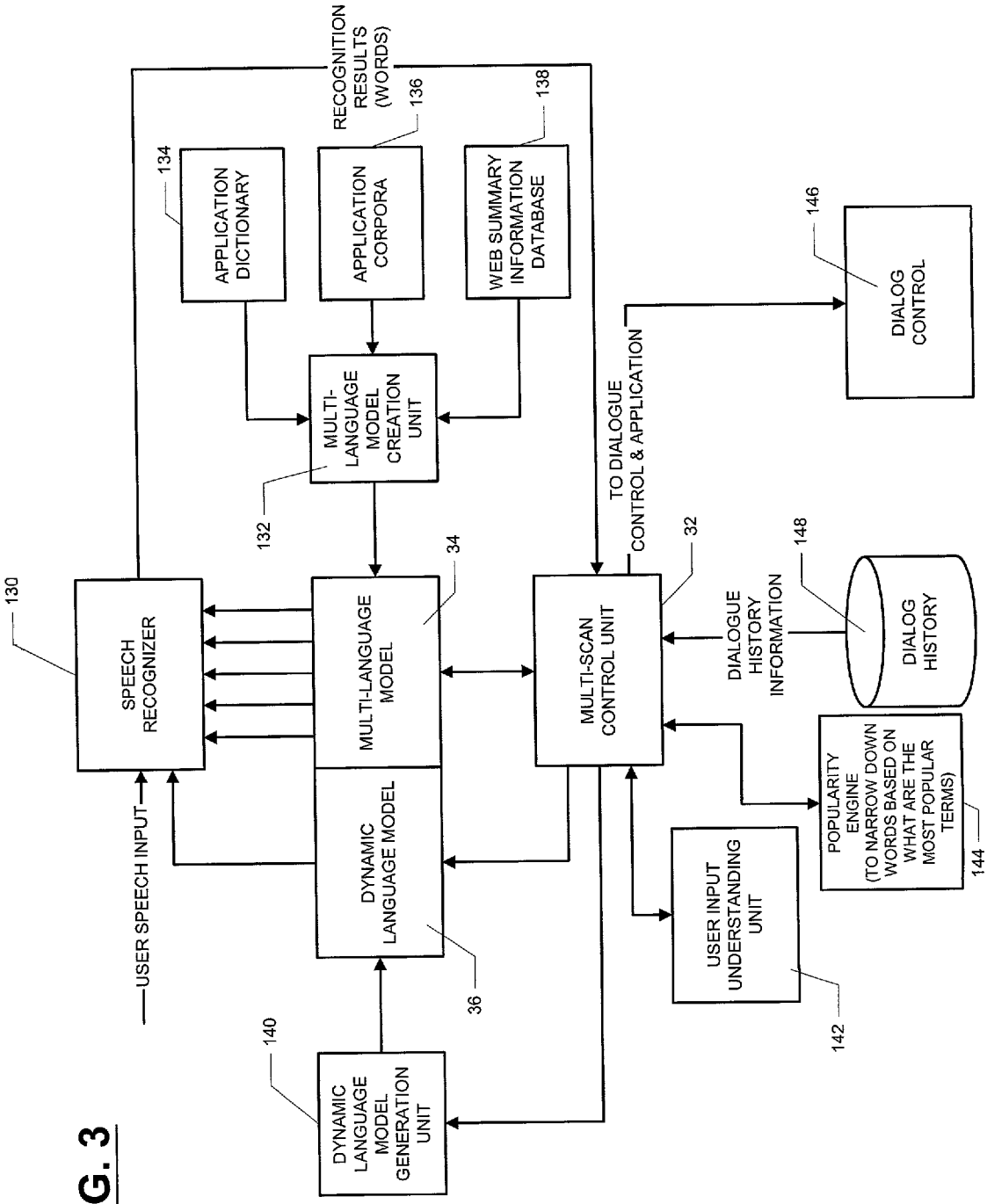

RECOGNITION RESULTS (WORDS)
134
APPLICATION DICTIONARY
136
APPLICATION CORPORA
138
WEB SUMMARY INFORMATION DATABASE
146
DIALOG CONTROL
MULTI-LANGUAGE MODEL CREATION UNIT
132
TO DIALOGUE CONTROL & APPLICATION
130
SPEECH RECOGNIZER
34
MULTI-LANGUAGE MODEL
32
MULTI-SCAN CONTROL UNIT
148
DIALOGUE HISTORY INFORMATION
DIALOG HISTORY
POPULARITY ENGINE (TO NARROW DOWN WORDS BASED ON WHAT ARE THE MOST POPULAR TERMS)
144
USER SPEECH INPUT
DYNAMIC LANGUAGE MODEL
36
USER INPUT UNDERSTANDING UNIT
142
140
DYNAMIC LANGUAGE MODEL GENERATION UNIT

FIG. 3

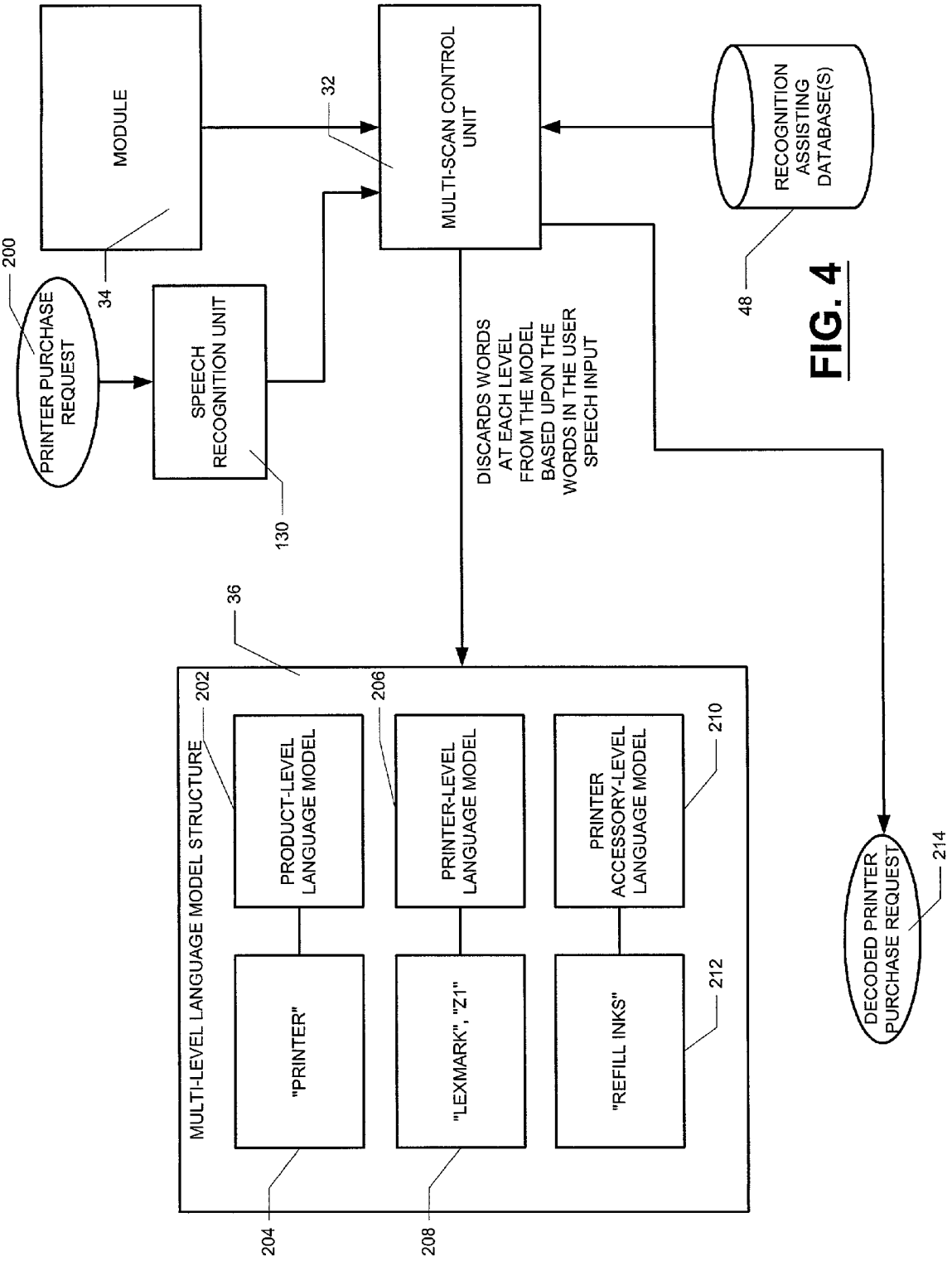

MODULE
34
32
MULTI-SCAN CONTROL UNIT
RECOGNITION ASSISTING DATABASE(S)
48
200
PRINTER PURCHASE REQUEST
SPEECH RECOGNITION UNIT
130
DISCARDS WORDS AT EACH LEVEL FROM THE MODEL BASED UPON THE WORDS IN THE USER SPEECH INPUT
36
MULTI-LEVEL LANGUAGE MODEL STRUCTURE
202
PRODUCT-LEVEL LANGUAGE MODEL
206
PRINTER-LEVEL LANGUAGE MODEL
PRINTER ACCESSORY-LEVEL LANGUAGE MODEL
210
"PRINTER"
"LEXMARK", "Z1"
"REFILL INKS"
212
204
208
DECODED PRINTER PURCHASE REQUEST
214

FIG. 4

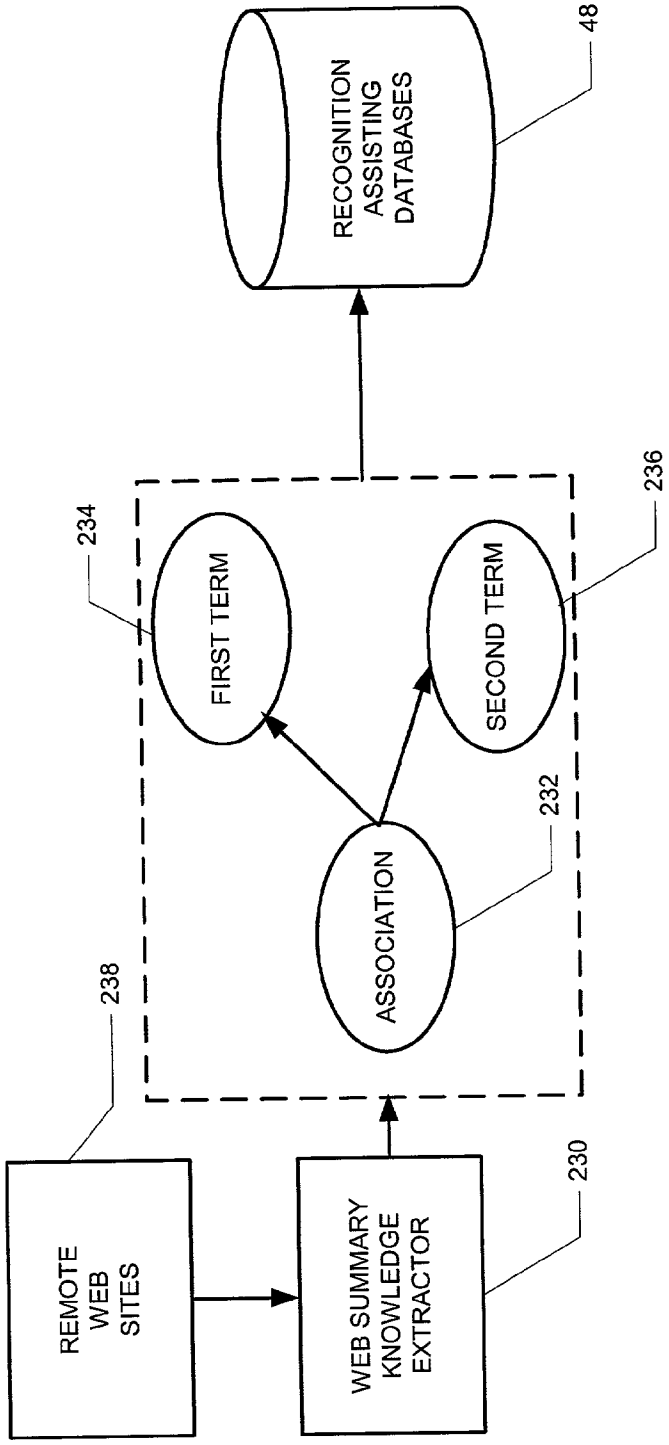

REMOTE WEB SITES
238
WEB SUMMARY KNOWLEDGE EXTRACTOR
230
ASSOCIATION
232
FIRST TERM
234
SECOND TERM
236
RECOGNITION ASSISTING DATABASES
48

FIG. 5

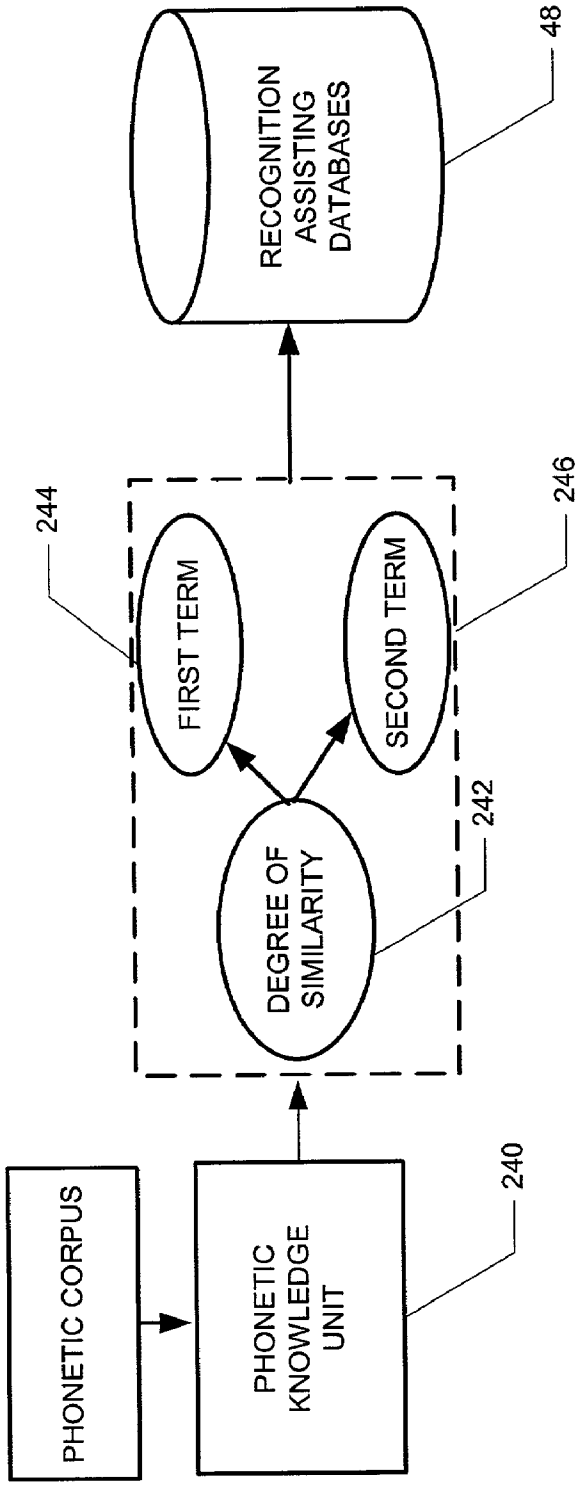

PHONETIC CORPUS
PHONETIC KNOWLEDGE UNIT
240
DEGREE OF SIMILARITY
242
FIRST TERM
244
SECOND TERM
246
RECOGNITION ASSISTING DATABASES
48

FIG. 6

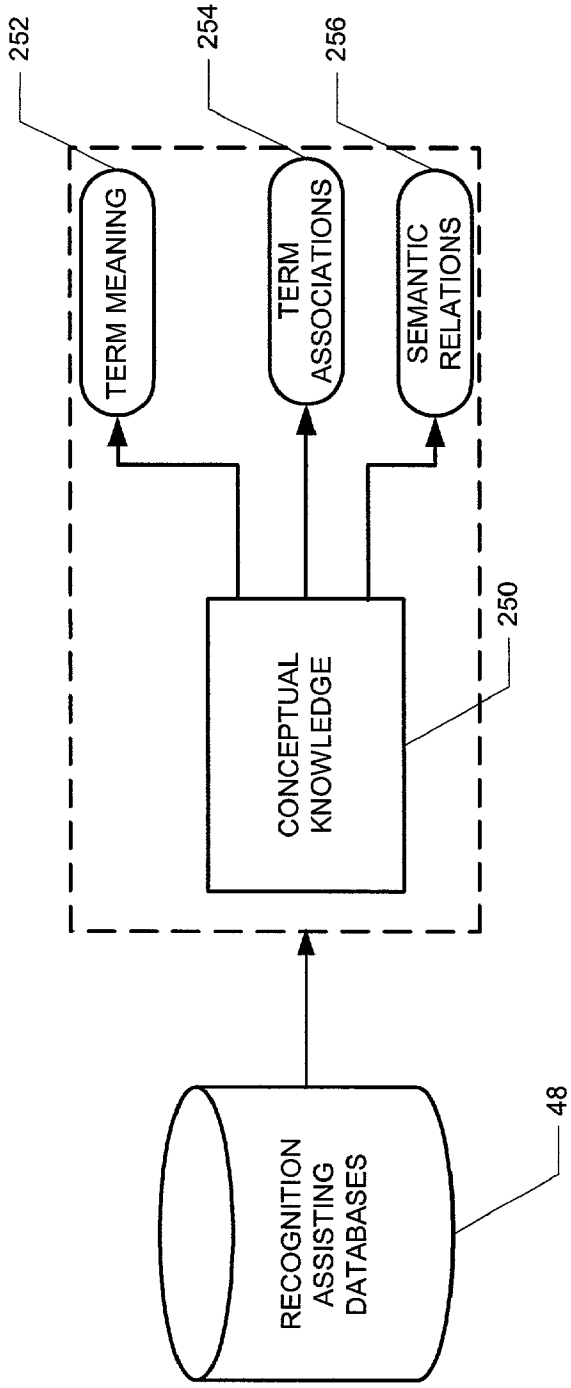

252
254
256
TERM MEANING
TERM ASSOCIATIONS
SEMANTIC RELATIONS
CONCEPTUAL KNOWLEDGE
250
RECOGNITION ASSISTING DATABASES
48

FIG. 7

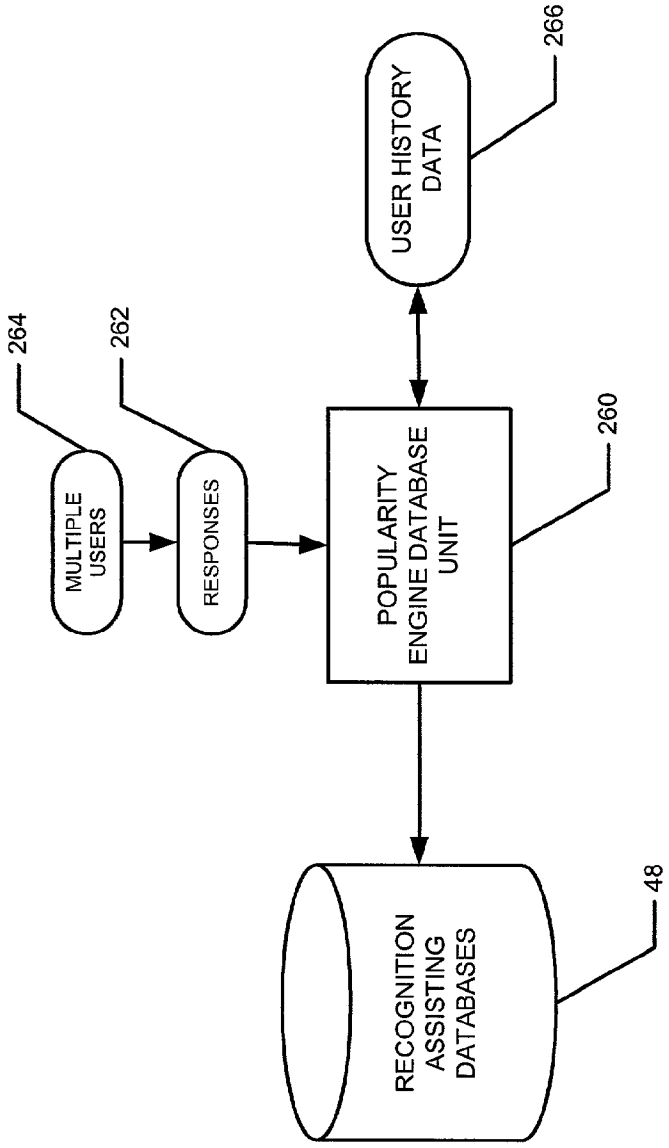

MULTIPLE USERS
264
RESPONSES
262
USER HISTORY DATA
266
POPULARITY ENGINE DATABASE UNIT
260
RECOGNITION ASSISTING DATABASES
48

FIG. 8

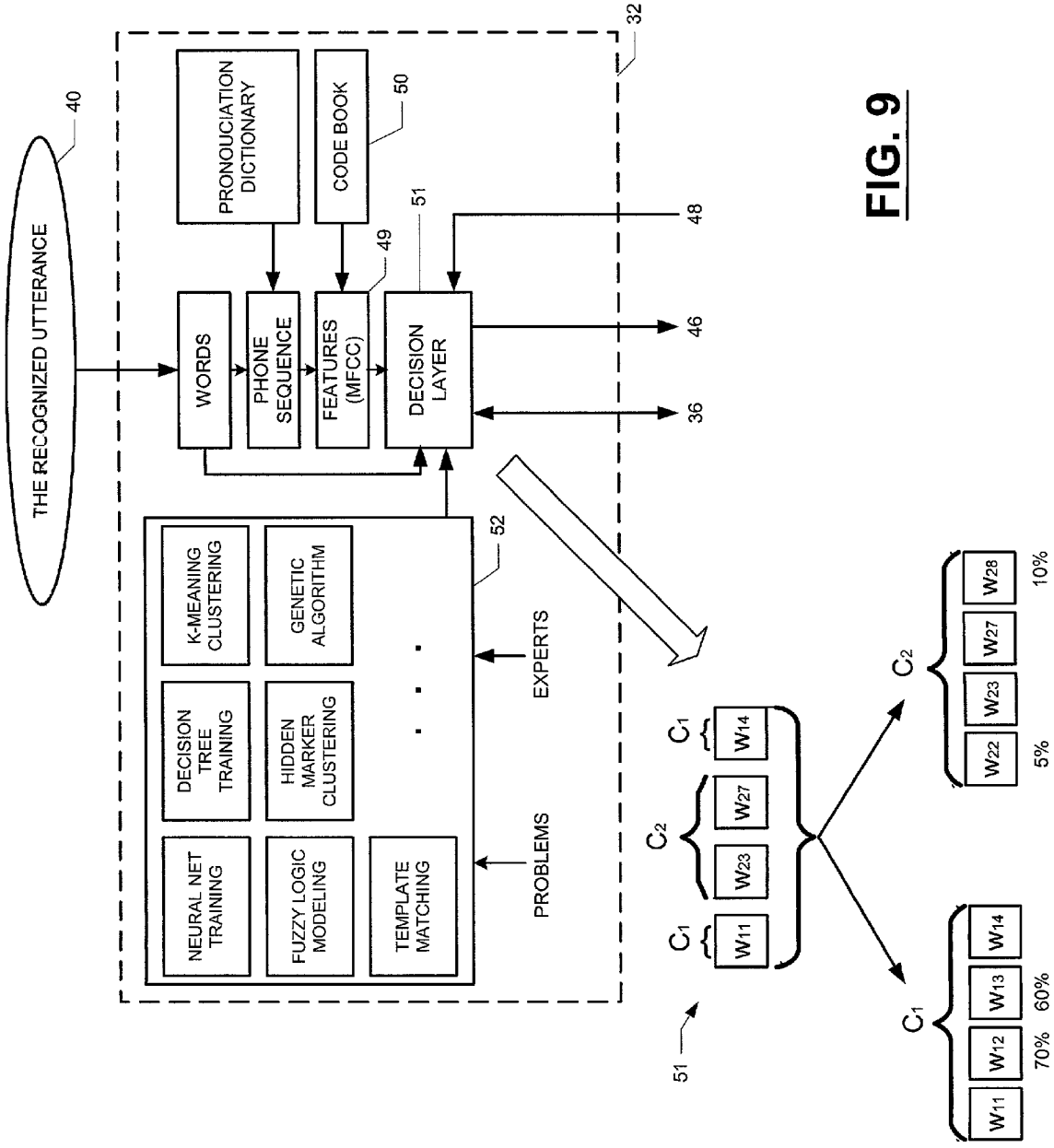

THE RECOGNIZED UTTERANCE
40
32
PRONOUCIATION DICTIONARY
CODE BOOK
50
WORDS
PHONE SEQUENCE
FEATURES (MFCC)
49
DECISION LAYER
51
48
46
36
K-MEANING CLUSTERING
GENETIC ALGORITHM
DECISION TREE TRAINING
HIDDEN MARKER CLUSTERING
NEURAL NET TRAINING
FUZZY LOGIC MODELING
TEMPLATE MATCHING
52
EXPERTS
PROBLEMS
51
C1
C2
W11
W23
W27
W14
W12
W13
W22
W28
70%
60%
5%
10%

FIG. 9

COMPUTER-IMPLEMENTED MULTI-SCANNING LANGUAGE METHOD AND SYSTEM

RELATED APPLICATION

[0001] This application claims priority to U.S. provisional application Serial No. 60/258,911 entitled "Voice Portal Management System and Method" filed Dec. 29, 2000. By this reference, the full disclosure, including the drawings, of U.S. provisional application Serial No. 60/258,911 are incorporated herein.

FIELD OF THE INVENTION

[0002] The present invention relates generally to computer speech processing systems and more particularly, to computer systems that recognize speech.

BACKGROUND AND SUMMARY OF THE INVENTION

[0003] Previous speech recognition systems have been limited in the size of the word dictionary that may be used to recognize a user's speech. This has limited the scope of such speech recognition system to handle a wide variety of user's spoken requests. The present invention overcomes this and other disadvantages of previous approaches. In accordance with the teachings of the present invention, a computer-implemented method and system are provided for speech recognition of a user speech input. The user speech input which contains utterances from a user is received. A first language model recognizes at least a portion of the utterances from the user speech input. The first language model has utterance terms that form a general category. A second language model is selected based upon the identified utterances from use of the first language model. The second language model contains utterance terms that are a specific category of the general category of utterance terms in the first language model. The utterance in the specific category is recognized with the selected second language model from the user speech input.

[0004] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood however that the detailed description and specific examples, while indicating preferred embodiments of the invention, are intended for purposes of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0006] **FIG. 1** is a system block diagram depicting the software-implemented components of the present invention used to recognize utterances of a user;

[0007] **FIG. 2** is flowchart depicting the steps used by the present invention in order to recognize utterances of a user;

[0008] **FIG. 3** is a system block diagram depicting utilization of the present invention additional tools to recognize utterances of a user;

[0009] **FIG. 4** is a system block diagram an example of the present invention in processing a printer purchase request;

[0010] FIGS. **5-8** are block diagrams depicting various recognition assisting databases; and

[0011] **FIG. 9** is a system block diagram depicting an embodiment of the present invention for selecting language models.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012] **FIG. 1** depicts the speech recognition system **28** of the present invention. The speech recognition system **28** analyses user speech input **30** by applying multiple language models **36** organized for multi-level information detection. The language models form conceptually-based hierarchical tree structures **36** in which top-level models **38** detect a generic term, while lower-level sub-models **42** detect increasingly specific terminology. Each language model contains a limited number of words related to a predicted area of user interest. This domain specific model is more flexible than existing keyword systems that detect only one word in an utterance and use that word as a command to take the user to the next level in the menu.

[0013] The speech recognition system **28** includes a multi-scan control unit **32** that iteratively selects and scans models from the multiple language models **36**. The multiple language models **36** may be hidden Markov language models that are domain specific and at different levels of specificity. Hidden Markov models are described generally in such references as "Robustness In Automatic Speech Recognition", Jean Claude Junqua et al., Kluwer Academic Publishers, Norwell, Mass., 1996, pages 90-102. The models in the multiple language models **36** are of varying scope. For example, one language model may be directed to the general category of printers and includes such top level product information as language models to differentiate among various computer products such as printer, desktop, and notebook. Other language models may include more specific categories within a product. For example, for the printer product, specific product brands may be included in the model, such as Lexmark or Hewlett-Packard.

[0014] The multi-scan control unit **32** examines the user's speech input **30** to recognize the most general word in the speech input **30**. The multi-scan control unit **32** selects the most general model from the multiple language models **36** that contains at least one of the general words found within the speech input **30**. The multi-scan control unit **32** uses the selected model as the top-level language model **38** within the hierarchy **36**. The multi-scan control unit **32** recognizes words via the top-level language model **38** in order to form the top-level word level data set **40**.

[0015] The top-level word data set contains the words that are currently recognized in the speech input **30**. The recognized words in data set **40** are used to select the next model from the multi-language models **34**. Typically, the next selected language model is a model that is a more specific domain within the top-level language model **38**. For example, if the top-level language model **38** is a general products language model, and the user speech input **30** contains the term printer, then the next model retrieved from the multi-language models **34** would contain more specific

printer product words, such as Lexmark. The multi-scan control unit **32** iteratively selects and applies more specific models from the multi-language models **34** until the words in the speech input **30** have been sufficiently recognized so as to be able to perform the application at hand. In this way, one or more specific language models **42**, **44** identify more specific words in the user speech input **30**.

[**0016**] For example, the multi-scan unit **32** iteratively uses language models from the model hierarchy **36** so as to recognize a sufficient number of words to be able to process a request from a user to purchase a specific printer. The recognized input speech **46** for that example may be sent to an electronic commerce transaction computer server in order to facilitate the printer purchase request. The multi-scan control unit **32** may utilize recognition assisting databases **48** to further supplement recognition of the speech input **30**. The recognition assisting databases **48** may include what words are typically found together in a speech input. Such information may be extracted by analyzing word usage on internet web pages. Another exemplary database to assist word recognition is a database that maintains personalized profile that already have been recognized for a particular user or for users that have previously submitted requests which are similar to the request at hand. Previously recognized utterances are also used to assist the database. For example, if a user had previously asked for prices for a Lexmark printer, the words recognized in that previous time would be used to assist in recognizing those words again in this current speech input **30**. Other databases to assist in word recognition are discussed below.

[**0017**] **FIG. 2** depicts the steps used by the present invention in order to recognize words by a multiple scan of a user's input speech. Start block **60** indicates that process block **62** receives the user's request. Process block **63** performs the initial word recognition that is used by process block **64** to select a top-level language model. Process block **64** selects the model from the multiple language models that most probably matches the context of the user's request. For example, if the user's request is focused upon purchasing a product, then the top-level product language model is used to recognize words in the user's request. Selection of the top level language model is context and application specific. For example in a weather service telephony application, the top level language model may be selected based upon the phone number dialed by a user within a telephony system. The phone number is associated with what language should be initially used. However, it should be understood that for some top level language model designs, especially ones that have a wide variety of applications, the initial recognition may be necessary in order to determine which specific language model should be used.

[**0018**] Process block **66** scans the user request with the selected top-level language model. The scan by process block **66** results in words being associated with recognition probabilities. For example, the word "printer" which is found in the top-level language model has a high degree of likelihood of being recognized, whereas other words such as "Lexmark" which is not in the product top-level language model would normally come out as phone-based filler words. Process block **68** applies the recognition assisting databases in order to further determine the certainty of recognized words. The databases may increase the probability score or decrease the probability score depending upon the comparison between the recognized words and the data that is found in the speech recognition assisting databases. From the scans of process block **66** and process block **68**, process block **70** reconfirms the recognized words by parsing the word string. The parsed words are fit into a syntactic model that contains slots for the different syntactic types of words. Such slots include a subject slot, a verb slot, etc. Slots that are not filled are used to indicate what additional information may be needed from the user.

[**0019**] Decision block **72** examines whether additional scans are needed in order to recognize more words in the user request or to reassess the recognition probabilities of the already recognized words. This determination by decision block **72** as to whether additional scans are needed is more specifically based upon the degree in which the recognition of the utterance is parsed by a syntactic-semantic parser, and whether the recognized key elements (such as nouns and verbs) is sufficient for further action. If decision block **72** determines that an additional scan is needed, process block **74** selects a lower-level language model based upon the words that have already been recognized. For example, if the word "printer" has already been recognized, then the specific printer products language model is selected.

[**0020**] Process block **66** scans the user input again using the selected lower-level language model of process block **74**. Process block **68** scans the user input with the recognition assisting databases to increase or decrease the recognition probabilities of the words that were recognized during the scan of process block **66**. Process block **70** parses the list of the recognized words. Decision block **72** examines whether additional scans are needed. If a sufficient number of words or all of the words have been satisfactorily recognized, then the recognized words are provided as output for use within the application at hand. Processing terminates at end block **78**.

[**0021**] **FIG. 3** depicts a detailed embodiment of the present invention. With reference to **FIG. 3**, the speech recognition unit or decoder **130** scans (or maps) user utterances from a telephony routing system. Recognition results are passed to the multi-scan control unit **32**. The speech recognition unit **130** uses the multi-language models **34** and dynamic language model **36** in its Viterbi search process to obtain recognition hypotheses. The Viterbi search process is generally described in "Robustness In Automatic Speech Recognition", Jean Claude Junqua et al., Kluwer Academic Publishers, Norwell, Mass., 1996, page 97.

[**0022**] The multi-scan control unit **32** may relay information to a dialogue control unit **146**. It can receive information about the user's dialogue history **148** and information from the understanding unit **142** about concepts. The user input understanding unit **142** contains conceptual data from personal user profiles based on the user's usage history. The multi-scan control unit **32** sends data to the dynamic language model generation unit **140**, the dynamic language model **36**, and the multi-language models **34** in order to facilitate the creation of dynamic language models, and the sequence in which they will be scanned in a multi-scanning process.

[**0023**] The multi-language model creation unit **132** has access to the application dictionary **134**, containing the corpus of the domain in use, the application corpora **136**, and the web summary information database **138** containing the

corpus from web sites. The multi-language model creation unit **132** determines how the sub-models are created, along with their hierarchical structure, in order to facilitate multi-scan process.

[**0024**] The popularity engine **144** contains data compiled from multiple users' histories that has been calculated for the prediction of likely user requests. This increases the accuracy of word recognition. Users belong to various user groups, distinguished on the basis of past behavior, and can be predicted to produce utterances containing keywords from language models relevant to, for example, shopping or weather related services.

[**0025**] The user speech input is detected by the speech recognition system **130** and is partitioned into phonetic components for scanning by multiple language models and is turned into recognition hypotheses as word strings. The multi-scan control unit **32** chooses the relevant multi-language model **34** for scanning to match the input for recognizable keywords that indicate the most likely context for the user request. A multi-language model creation unit **132** accesses databases to create multi-models. It makes use of the application dictionary **134** and application corpora **136** containing terms for the domain applications in use, or the web summary information database **138** which contains terms retrieved from relevant web sites. When required, the multi-scan control unit **32** can use a dynamic language model **36** that contains subsets of words for refining a more specific context for the user request, allowing the correct words to be found.

[**0026**] The dynamic language model generation unit **140** generates new models based on user collocations and areas of interest, allowing the system to accommodate an increasing variety of usage. The user input understanding unit **142** accesses the user's personal profile determined by usage history to further refine output from the multi-scan control unit **32** and relays the output to the dynamic language model generation unit **140**. The popularity engine **144** also has an impact on the output of the multi-scan control unit **32**, directing scanning for the most probable match for words in the user utterance based on past requests.

[**0027**] **FIG. 4** depicts a scenario where the user wishes to buy an inkjet cartridge for a particular printer. Note that the bracketed words below represent what the user says but are not recognized as they are not included in the language model being used. Therefore they usually come out as filler words such as a phone-based filler sequence. The speech recognition unit **130** relays, "Do you sell [refill ink] for [Lexmark Z11] inkjet printers?" to the multi-scan control unit **32**. The query is scanned and the word "printer"**204** in the general product name model **202** triggers an additional scanning by the subset model **206** for printers. This subset discards words like "laser" and "dot matrix" and goes to the inkjet product sub-model, which contains the particular brand and model number and eliminates other brands and models. The terms "Lexmark" and "Z11"**208** are recognized by model **206**. The next subset contains a printer accessories model **210**, and "refill ink"**212** from the user request is detected, eliminating other subset possibilities, and arriving at an accurate decoding **214** of the user input speech request. The recognition assisting databases **48** assisted the multi-scan control unit **32** by providing the multi-scanned models with the most popular words about printers, as well as the most commonly used phrases by the user. This information is collected from the web, previous utterances, as well as relevant databases.

[**0028**] **FIG. 5** depicts the web summary knowledge database **230** that forms one of the recognition assisting databases **48**. The web summary information database **230** contains terms and summaries derived from relevant web sites **238**. The web summary knowledge database **230** contains information that has been reorganized from the web sites **238** so as to store the topology of each site **238**. Using structure and relative link information, it filters out irrelevant and undesirable information including figures, ads, graphics, Flash and Java scripts. The remaining content of each page is categorized, classified and itemized. Through what terms are used on the web sites **238**, the web summary database **230** forms associations **232** between terms (**234** and **236**). For example, the web summary database may contain a summary of the Amazon.com web site and creates an association "topic-media" between the term "golf" and "book" based upon the summary. Therefore, if a user input speech contains terms similar to "golf" and "book", the present invention uses the association **232** in the web summary knowledge database **230** to heighten the recognition probability of the terms "golf" and "book" in the user input speech.

[**0029**] **FIG. 6** depicts the phonetic knowledge unit **240** that forms one of the recognition assisting databases **48**. The phonetic knowledge unit **240** encompasses the degree of similarity **242** between pronunciations for distinct terms **244** and **246**. The phonetic knowledge unit **240** understands basic units of sound for the pronunciation of words and sound to letter conversion rules. If, for example, a user requested information on the weather in Tahoma, the phonetic knowledge unit **240** is used to generate a subset of names with similar pronunciation to Tahoma. Thus, Tahoma, Sonoma, and Pomona may be grouped together in a node specific language model for terms with similar sounds. The present invention analyzes the group with other speech recognition techniques to determine the most likely correct word.

[**0030**] **FIG. 7** depicts the conceptual knowledge database unit **250** that forms one of the recognition assisting databases **48**. The conceptual knowledge database unit **250** encompasses the comprehension of word concept structure and relations. The conceptual knowledge unit **250** understands the meanings **252** of terms in the corpora and the conceptual relationships between terms/words. The term corpora means a large collection of phonemes, accents, sound files, noises and pre-recorded words.

[**0031**] The conceptual knowledge database unit **250** provides a knowledge base of conceptual relationships among words, thus providing a framework for understanding natural language. For example, the conceptual knowledge database unit contains associations **254** between the term "golf ball" with the concept of "product". As another example, the term "Amazon.com" is associated with the concept of "store". These associations are formed by scanning websites, to obtain conceptual relationships between words, categories, and their contextual relationship within sentences.

[**0032**] The conceptual knowledge database unit **250** also contains knowledge of semantic relations **256** between

words, or clusters of words, that bear concepts. For example, "programming in Java" has the semantic relation: "action-means".

[0033] **FIG. 8** depicts the popularity engine database unit **260** that forms one of the recognition assisting databases **48**. The popularity engine database unit **260** contains data compiled from multiple users' histories that has been calculated for the prediction of likely user requests. The histories are compiled from the previous responses **262** of the multiple users **264**. The response history compilation **266** of the popularity engine database unit **260** increases the accuracy of word recognition. Users belong to various user groups, distinguished on the basis of past behavior, and can be predicted to produce utterances containing keywords from language models relevant to, for example, shopping or weather related services.

[0034] **FIG. 9** depicts an embodiment of the present invention for selecting language models. This embodiment utilizes a combination of statistical modeling and conceptual pattern matching with both semantic and phonetic information. The multi-scan control unit **32** receives an initially recognized utterance **40** from the user as a word sequence. The output is first normalized to a standard format. Next semantic and phonetic features are extracted from the normalized word sequence. Then the acoustic features of the input utterance, in the form of Mel-Frequency Cepstral Coefficients (mfcc) **49**, of each frame of the input utterance is mapped against the code book models **50** of each of the phonetic segment of the recognized words to calculate their confidence levels. The semantic feature of the recognized words is represented as attribute-and-value matrices. These include semantic category, syntactic category, application-relevancy, topic-indicator, etc. This representation is then fed into a multi-layer perceptron-based neural network decision layer **51**, which has been trained by the learning module **52** to map feature structures to sub-language models **36**. A sub-language model reflects certain user interests. It could mean a switching from a portal top level node to a specific application; it could also mean a switching from an application top-level node to a special topic or user interest area in that application. The joint use of semantic information and phonetic information has the effect of mutual-supplementation between the words. For example, if two words W1 and W2 are recognized, **51**, W1 being correct and W2 being wrong, when matching a conceptual pattern of a correct sub-model (i.e., the first category "C1" sub-model), W1 will have a high semantic score and at the same time W2 will have a high phonetic score as its phonetic and the acoustic feature will match up a word which is mis-recognized. On the other hand, when matching a conceptual pattern from a wrong sub-model (i.e., C2), the semantic score of W1 as well as its phonetic score will all be low, as there is unlikely a word in the wrong pattern having similar pronunciation to it. To further illustrate this point, imagine the user says "I want a Lexmark printer" and the recognizer gives "I want a Lexus printer". Now imagine two contending sub-models are tried. The C1 sub-model contains words like "I want a Lexmark printer" the second one (C2 sub-model) contains words like "I want a Lexus car". The C1 sub-model has a significantly higher chance of being selected if both semantic and phonetic information are jointly used. The joint information of semantic and phonetic features is also used to partition large word sets within a conceptual sub-model into further phonetic sub-models.

[0035] The preferred embodiment described within this document with reference to the drawing figure(s) is presented only to demonstrate an example of the invention. Additional and/or alternative embodiments of the invention will be apparent to one of ordinary skill in the art upon reading the aforementioned disclosure.

It is claimed:

1. A computer-implemented method for speech recognition of a user speech input, comprising the steps of:

receiving the user speech input that contains utterances from a user;

recognizing by a first language model at least a portion of the utterances from the user speech input, said first language model having utterance terms that form a general category;

selecting a second language model based upon the identified utterances from use of the first language model, said second language model containing utterance terms that are a subset category of the general category of utterance terms in the first language model; and

recognizing with the selected second language model utterances from the user speech input.

2. The method of claim 1 wherein a hierarchy of language models that progresses from general terms to specific terms is used to recognize the utterances from the user speech input.

3. The method of claim 2 further comprising the steps of:

selecting the first language model from the hierarchy of language models to recognize context of the user speech input;

selecting based upon the recognized context of the user speech input the second language model from the hierarchy of language models;

using the selected second language model to recognize specific terms within the user speech input;

using the recognized specific terms to select a third language model from the hierarchy of language models; and

using the selected second language model to recognize terms within the user speech input.

4. The method of claim 3 wherein the language models regard domains, wherein hierarchy of language models is organized based upon the domain to which a language model is directed.

5. The method of claim 4 wherein the language models are hidden Markov language recognition models.

6. The method of claim 3 further comprising the step of:

providing the recognized utterances of the user input speech to an electronic commerce transaction computer server in order to process request of the user input speech.

7. The method of claim 2 further comprising the step of:

using models within the hierarchy of language models for recognizing idioms in the user input speech.

8. The method of claim 1 wherein a web summary knowledge database stores associations between first terms and second terms, wherein the associations indicate that when a first term is used its associated second term has a

likelihood to be present, wherein Internet web pages are processed in order to determine the associations between the first and second terms, said method further comprising the step of:

using the stored associations to recognize the utterances within the user input speech.

9. The method of claim 1 wherein a phonetic knowledge unit stores the degree of pronunciation similarity between a first and second term, wherein the phonetic knowledge unit is used to select terms of similar pronunciation for storage in the second language model.

10. The method of claim 1 wherein a conceptual knowledge database unit stores word concept structure and relations, said method further comprising the step of:

using the stored word concept structure and relations to recognize the utterances within the user input speech.

11. The method of claim 1 wherein the recognized utterances are used within a telephony system.

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