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Baker et al.

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[54] **SYSTEMS AND METHODS FOR WORD RECOGNITION**

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[52] **U.S. Cl.** **395/2.66**; 395/2.64; 395/2.6

[58] **Field of Search** 364/419.02, 419.03, 364/419.08; 395/2.6, 2.61, 2.64, 2.66, 2.4, 2.44, 2.79, 2.69, 2.86, 2.85, 2.52, 2.84

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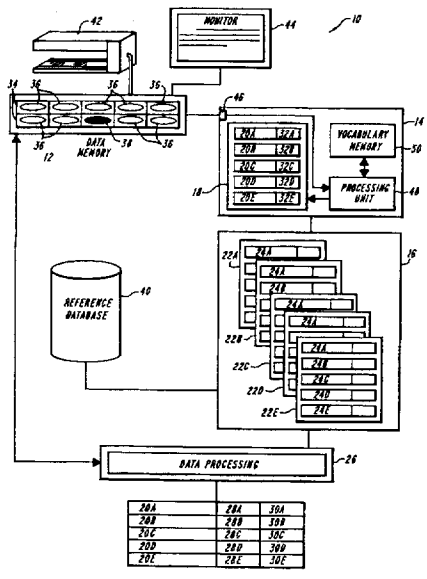
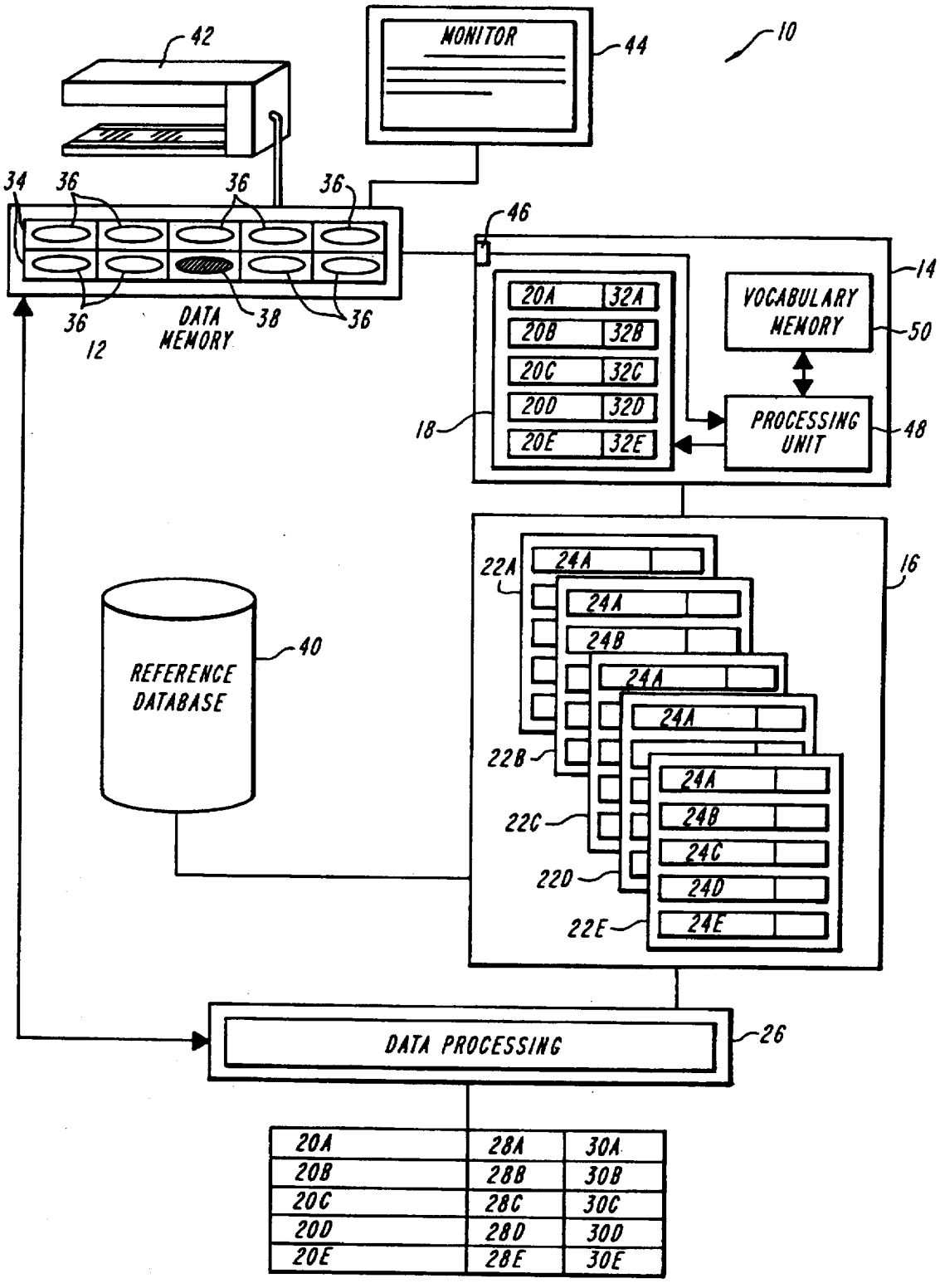
Assistant Examiner—Daniel S. Hunter
Attorney, Agent, or Firm—Thomas J. Engellenner; Lawrence E. Monks; Lahive & Cockfield, LLP

[57] **ABSTRACT**

In one aspect, the invention provides word recognition systems that operate to recognize an unrecognized or ambiguous word that occurs within a passage of words. The system can offer several words as choice words for inserting into the passage to replace the unrecognized word. The system can select the best choice word by using the choice word to extract from a reference source, sample passages of text that relate to the choice word. For example, the system can select the dictionary passage that defines the choice word. The system then compares the selected passage to the current passage, and generates a score that indicates the likelihood that the choice word would occur within that passage of text. The system can select the choice word with the best score to substitute into the passage. The passage of words being analyzed can be any word sequence including an utterance, a portion of handwritten text, a portion of typewritten text or other such sequence of words, numbers and characters. Alternative embodiments of the present invention are disclosed which function to retrieve documents from a library as a function of context.

43 Claims, 5 Drawing Sheets




42
MONITOR
44
10
34
36
36
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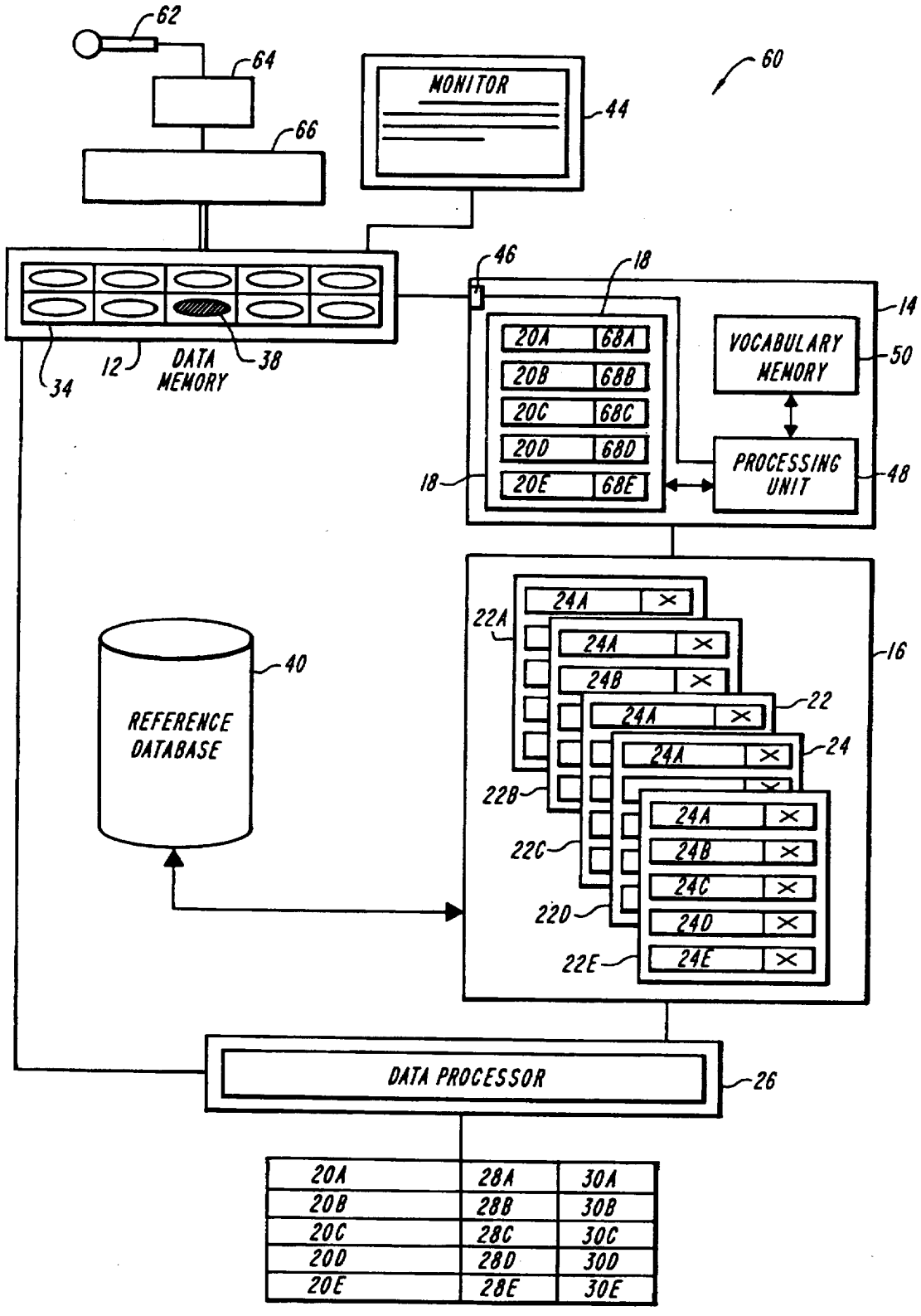
46
14
20A
32A
20B
32B
20C
32C
20D
32D
20E
32E
VOCABULARY MEMORY
50
36
DATA MEMORY
38
36
12
18
PROCESSING UNIT
48
22A
24A
16
24A
24B
24A
24A
22B
24A
22C
24B
24C
22D
24D
22E
24E
REFERENCE DATABASE
40
DATA PROCESSING
26
20A 28A 30A
20B 28B 30B
20C 28C 30C
20D 28D 30D
20E 28E 30E

FIG. 1


62
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MONITOR
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20A 68A
20B 68B
20C 68C
20D 68D
20E 68E
VOCABULARY MEMORY
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PROCESSING UNIT
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12
DATA MEMORY
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REFERENCE DATABASE
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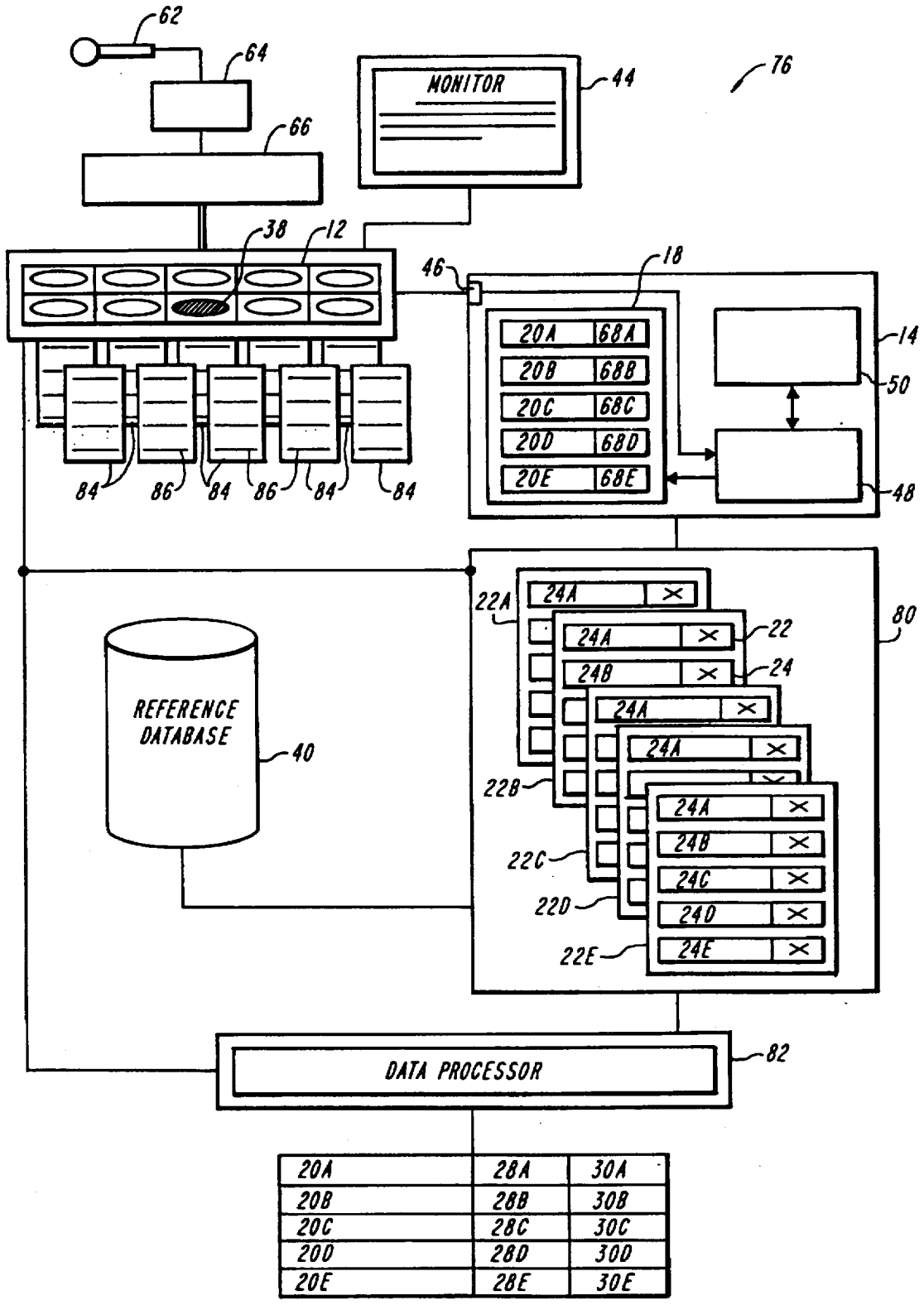
22A
24A
24B
22
24
22B
22C
24C
22D
24D
22E
24E
16
DATA PROCESSOR
26
20A 28A 30A
20B 28B 30B
20C 28C 30C
20D 28D 30D
20E 28E 30E

FIG. 2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MONITOR
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12
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20A
68A
20B
68B
20C
68C
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20E
68E
14
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48
84
86
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86
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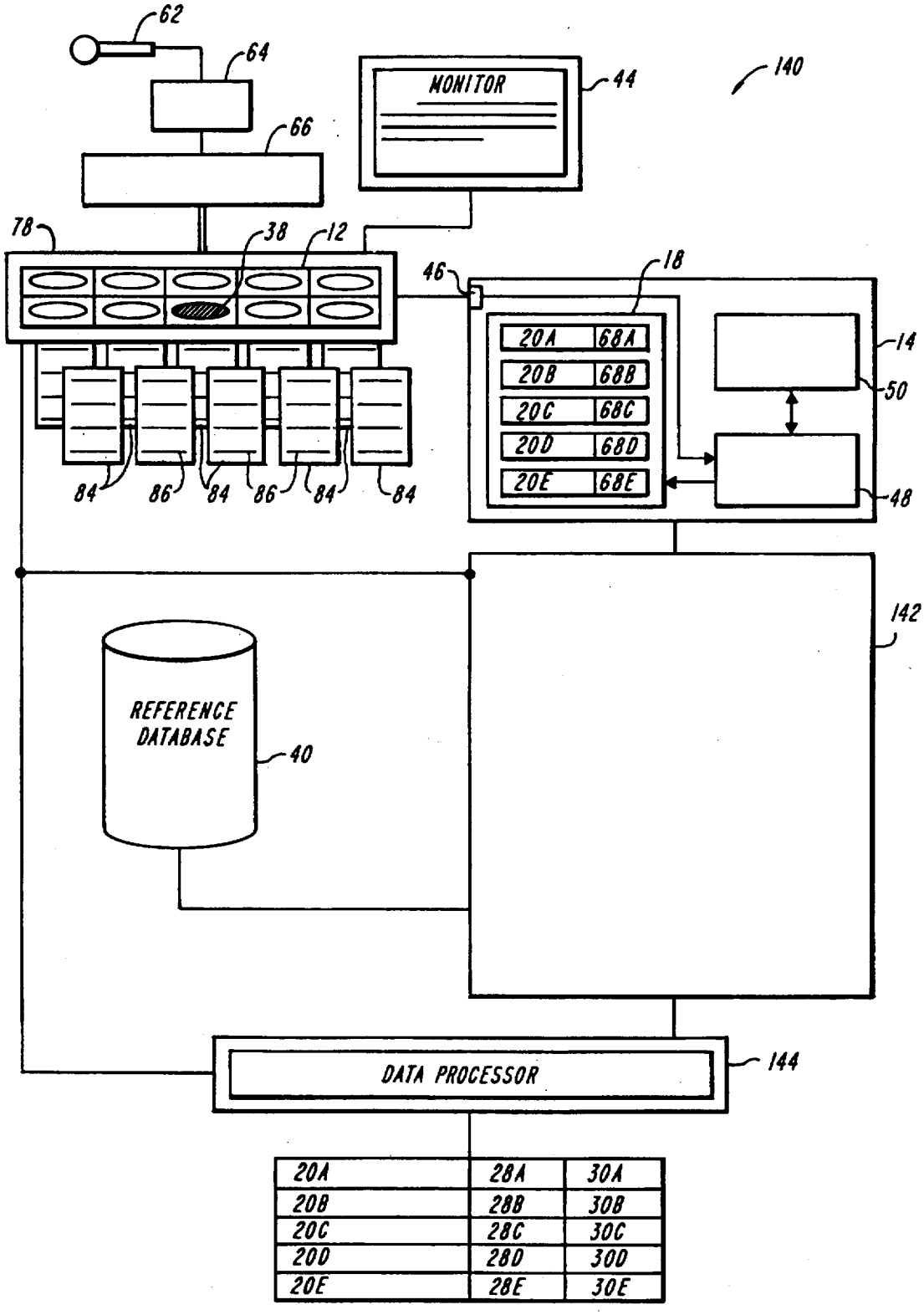
84
REFERENCE DATABASE
40
22A
24A
22
24A
24
24B
24A
24A
22B
24A
24B
22C
24C
22D
24D
22E
24E
80
DATA PROCESSOR
82
20A 28A 30A
20B 28B 30B
20C 28C 30C
20D 28D 30D
20E 28E 30E

FIG. 3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MONITOR
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140
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12
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68A
20B
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20C
68C
20D
68D
20E
68E
14
50
48
84
86
84
86
84
84
142
REFERENCE DATABASE
40
DATA PROCESSOR
144
20A 28A 30A
20B 28B 30B
20C 28C 30C
20D 28D 30D
20E 28E 30E

FIG. 4

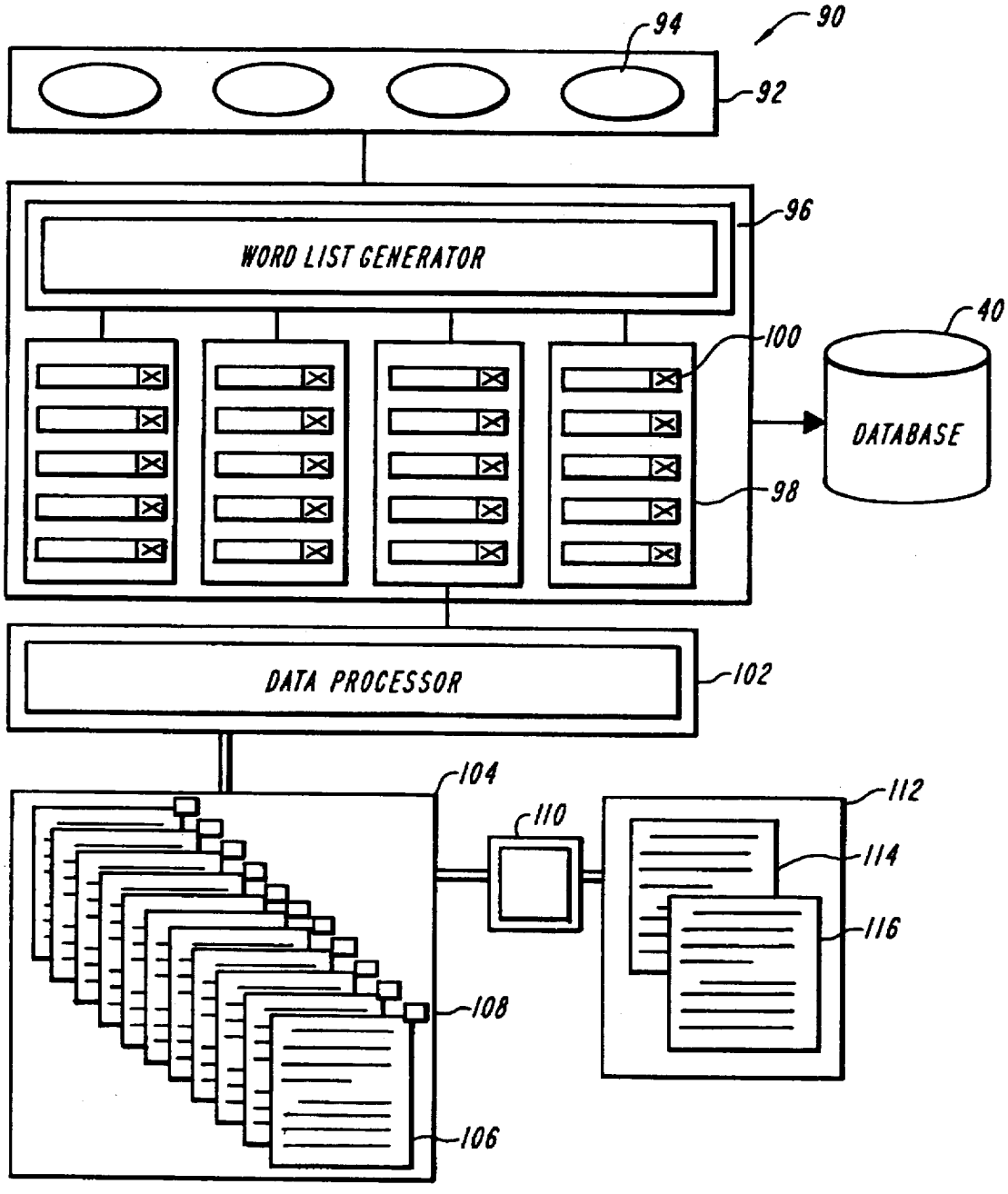
94
90
92
96
WORD LIST GENERATOR
40
100
DATABASE
98
DATA PROCESSOR
102
104
110
112
114
116
108
106

FIG. 5

SYSTEMS AND METHODS FOR WORD RECOGNITION

BACKGROUND OF THE INVENTION

This invention relates generally to methods and systems for word recognition, and, more particularly, to methods and systems that employ context and meaning to recognize a word, or a series of words.

Human beings are remarkably adept at manipulating sounds and images to communicate information. However, computers only communicate with information that is encoded as numerical data, most commonly a series of binary numbers. Therefore, to enter information, such as words, letters and numbers into a computer, the information must first be translated into machine-readable form.

Keyboard data entry is the conventional procedure for translating information into a computer-readable format. During a typical keyboard data entry process a computer operator types data, such as words and numbers, into the computer, and the keyboard generates a binary code for each key that is pressed. Therefore, the operator uses the keyboard to translate the data into a machine-readable format. Although keyboard data entry is a reliable procedure for entering data into a computer, it is a relatively time consuming and labor intensive process.

Word recognition, such as speech recognition or character recognition, is an alternative procedure for entering commands and information into a computer. In a word recognition procedure, an automated system recognizes each word by its sound, the shape of its letters, or some other characteristic, and generates the appropriate numerical data code. For example, during a speech recognition process, an operator dictates information into the computer and the computer recognizes the sounds of each word and enters the information into the computer, just as if the data were being typed. Similarly, in a character recognition process where there is handwritten input or an operator scans a document into a computer, the computer recognizes the shape of each character and generates the appropriate binary code as if the document were being retyped into the computer.

These recognition processes offer tremendous advantages over the conventional keyboard entry procedure. For example, speech recognition systems eliminate the need for typing and allow physically-challenged persons to operate computer automated equipment without having to key in data through a keyboard. Similarly, optical character recognition systems make clerical work more efficient by collecting data directly from documents without having to retype the documents into the computer.

In operation, a recognition system must first recognize each word or sequence of words in a document or in a speech before translating the word or words into the binary coded sequence. A basic word recognition system recognizes the words in a document or a speech on a word-by-word basis and analyzes each word individually, and sometimes independently, from the other words in the document. For example, a conventional character recognition system will separately analyze each word in a document to input the document one word at a time. Similarly, even complex word recognition systems, such as continuous speech systems, attempt to parse an utterance of speech into a series of individual words. Accordingly, these systems may analyze each word in isolation from the other words in the document or speech. Although these word-by-word systems generally work well, a major problem with these systems is that they are highly dependent on the quantity and quality of information available for each word in the document or speech.

Scientists have implemented context recognition procedures and systems that reduce the dependency of word recognition systems on the quality and quantity of information available for each word being analyzed. A context recognition system analyzes the known words in a word string to identify other words which are likely to occur in sequence with these known words. Conventional context recognition systems rely on data intensive language models to identify such other words. These language models are essentially statistical probability models that include a set of hypotheses as to what words are likely to appear in association with other words.

These statistical probability models typically include probability data collected by observing the frequency at which actual sequences of words occur in a set of documents, typically called the training data. Such a recognition system can employ these probabilities to help predict the next word in a sequence of words.

Accordingly, a basic concept in language modeling is to relate the current sentence or word sequence being analyzed to "similar" sequences which have been previously observed. However, prior art techniques based on this basic concept have significant limitations in their ability to compute and represent language knowledge. A fundamental difficulty arises because the number of all possible word sequences is impractically large. There are also difficulties in setting a practical definition for sequences to be "similar".

For example, the phrase in the previous paragraph: "a basic concept in language modeling . . . " might be said to be "similar" to all of the following:

1) A fundamental concept in language modeling

2) A concept in statistical language modeling

3) One key idea in the study of language

4) An important linguistic paradigm

One known language model, the word n-gram language model, identifies similar sequences by counting sequences of n words. With the n-gram language model, two word sequences are "similar" only if they are identical. Thus, among the above sample sequences, the only similarity recognized in example (1) is the sub phrase "concept in language modeling" and the only similarity in example (2) is the two word phrase "language modeling." No similarities exist in examples (3) and (4). Clearly, a word n-gram language model can miss most of the relationship between the word sequence being analyzed and similar observed phrases.

An additional problem with the word n-gram language model is that the number of possible word n-grams grows very large with increasing values of n. With a 60,000 word vocabulary the number of word pairs (bigrams) is 3.6 billion and the number of 3-grams is 216 trillion. If the counting of the word n-grams were generalized to use a broader definition of "similarity" of word sequences, it just makes the problem of representing the counts of observed sequences worse.

A prior art language model that has a broader definition of "similarity" than the word n-gram language model is the "semantic categories n-gram language model." In statistical modeling of sequences of semantic categories, each word in a sequence being analyzed is replaced by a label which represents some syntactic or semantic properties of the word. For example, in phrase (1) above, the word "fundamental" might be the same semantic category as "basic" and so the entire sequence would be judged to be similar to the original phrase. In example (2), the deletion of the word

"basic" and the insertion of the word "statistical" causes problems. Starting from the sample phrase, it is easy to generate phrases by deleting words, however, the number of phrases generated by all possible insertions is again overwhelming. Thus it is difficult to generalize prior art semantic category n-gram systems to properly model insertions and deletions.

Category n-gram systems have even more difficulty with examples (3) and (4). A category system might be able to form an association between "A basic concept" and "One key idea," but an n-gram system has no way to relate "the study of . . . " to ". . . modeling," and cannot handle the word order reversal. Category n-grams get little, if any, information from example (4).

Therefore, even though the category n-gram model allows a broader definition of similarity than word n-grams, they still do not allow the representation of anything approaching the full richness of language. Semantic categories also have another weakness which is separate from the limitations of n-gram methods in general. By definition, semantic category methods classify words into a finite set of "categories." The ability to represent sequences and n-grams with larger values of n can only be achieved by having the number of categories be much less than the number of words in the vocabulary. However, the actual semantic relationships in any natural language cannot be represented by any fixed partition into a limited number of categories. Words can be related to each other in a wide variety of ways. There is no set of words in which all the member words are all similar to each other and are not similar, in any way, to any word outside the set. Yet, the whole notion of categories, is predicated on the assumption that the entire vocabulary can be broken up into such sets.

However, there is a significant distinction between the notion of "semantic similarity" and the notion of "semantic categories". It is possible to say that two words are closely related and even put a quantitative measure on the degree of similarity. The problem comes in trying to encode such a similarity measure into a fixed set of categories. When all the different ways in which two words can be related are taken into account, it can be seen that the similarity function must depend on the actual identities of the two words. It is not understood to be possible to replace any set of words with any category label without loss of significant information.

Prior art methods like the n-gram language model, which rely on precomputed statistical counts, have the additional practical limitation of inherently requiring that the set of word sequences be mapped into a limited number of memory spaces or "bins." Whether the bins are determined by the identity of the word n-gram, by semantic categories, or by other means, the total number of bins is limited by the amount of available storage space, either computer memory (RAM) or disk storage. Consequently, these statistical language models require large amounts of permanent computer memory.

Another problem with existing language models is that they require substantial training to identify sufficient language characteristics to make feasible a context-based recognition system. Typically, training is done by analyzing the occurrence of words within machine-readable text and using the analyzed data to build a language model. However, to accurately model a system as extensive and as complex as general English, volumes and volumes of text, discussing many different topics, must be analyzed. As such, these language models require considerable off-line training to input and to analyze the contents of the training data.

This need for extensive off-line training creates another problem. In particular, successful off-line training is heavily dependent on a supply of training data sufficient to generate an adequate vocabulary of known words and adequate models of recognized language characteristics. However, sufficient training data is not always available, and the lack of useful training data is particularly acute for many important applications, such as applications in the scientific, medical or legal fields. Each field can have an extensive list of application-specific terms and meanings. In these cases, it is necessary to have extensive amounts of specific text, so that the language model can analyze sufficient statistical data to generate meaningful language characteristics and to have a sufficient vocabulary. When adequate training data is not readily available, it typically must be created by either entering data at a keyboard or translating data into a machine readable format by input into a recognition system. The production of training data adds to the expense and the time of developing language models.

Another constraint is that the available training data must accurately reflect the language being modeled to achieve high performance. For example, Dow Jones makes available an extensive amount of machine readable text from The Wall Street Journal. However, the text is skewed to emphasize financial terms and meanings, and is likely to overemphasize the correlation between the words "bank" and "loan" at the expense of the correlation between the words "bank" and "river". Additionally, the characteristics particular to a text can skew the language model, such as overemphasizing the correlation of the word "new" with the word "york". Therefore, the training data must be selected carefully and, if necessary, examined and edited so that it more accurately models the type of language. This is a time consuming and labor intensive process that greatly increases the expense and time associated with context word recognition systems.

Additionally, these conventional training techniques and their associated language models are difficult to adapt or edit. For instance, each new word, such as "obviousness", requires sufficient training text and analysis to develop a meaningful statistical model of the word. Therefore, each time a new word is added to the language model, new training data must be obtained or developed. This can be particularly burdensome in new fields of science, where new terms have a precise meaning but very little textual material is available that uses the term.

Moreover, these context models require a statistical analysis of the interrelationship between new words and already known words. To do this these systems must update the words in the model each time a new word is added to the vocabulary. This may require that the system be taken off-line, trained with the new data, tested and updated. This cumbersome process makes it difficult and impractical to develop such language models that are applicable in rapidly changing fields, such as computer science, biotechnology and political science.

As such, there is a need in the art of word recognition for improved systems and methods that can recognize words in a data string as a function of context and meaning, and in particular there is a need for systems and methods that require less training data and less training time.

SUMMARY OF THE INVENTION

The invention avoids many of the problems of prior art systems by, in one aspect, providing systems and methods that perform semantic and linguistic analysis on the fly, as the data is needed, rather than relying on pre-computed

statistical counts stored in predetermined bins. Accordingly, the invention, in one aspect, provides systems and methods that perform semantic analysis by analyzing language knowledge represented as, in one example, raw text, and employing the language knowledge for dynamically computing the semantic similarity between the words in a "sample passage" and the words in the "current passage" being analyzed.

In one aspect, the invention provides word recognition systems that operate to recognize an unrecognized or ambiguous word that occurs within a passage of words. Using known techniques, the system can offer several words as choice words to replace the unrecognized word. The system can select the best choice word by using the choice word to extract from a reference source sample passages of text that relate to the choice word. For example, the system can select the dictionary passage that defines the choice word or, if the choice word represents a phrase of two or more words, the system can select a dictionary passage that defines one of the words in the phrase. The system then compares the selected passage to the current passage, and generates a score that indicates the likelihood that the choice word would occur within that passage of text. The system can select the choice word with the best score to substitute into the passage.

Accordingly, the present invention provides systems and methods that represent language knowledge as actual sequences of text. In other examples, the language knowledge may be represented by a passage of raw text selected from an encyclopedia. Those skilled in the art of computer science will understand that there are other equivalent embodiments which may use different data structures and different encoding of the same language knowledge. However, it will be understood by one of ordinary skill in the art of computer science that any such alternate embodiments and practices are equivalent to the embodiments taught herein and can be practiced with the present invention without departing from the scope thereof.

To aid in understanding the description set forth herein, the following terms are explained.

The phrase "sample passage", as used herein, encompasses samples of text accessible to the recognition system during operation.

"Relevance indicator" as the term is used herein, encompasses dictionary headwords, lists of keywords, frequency counts of all words in a passage or any characterization of a sample passage which provides information for making a decision as to the relevance of a sample passage for a word recognition operation.

The phrase "current passage", as used herein, is understood to encompass a passage of words or phrases that are being analyzed by the system or method and that includes at least one word to be recognized.

The phrase "current word", as used herein, is understood to encompass the word or phrase on which the system or method is operating to estimate a probability distribution given the other words which are known, or hypothesized, to be in the current passage.

The phrase "context words", as used herein, encompasses the other words in the current passage, which may be used by the system or method to estimate a probability distribution for the current word being analyzed. It will be apparent to one of ordinary skill in the art of speech recognition, that context words encompass words in the current passage which have been explicitly confirmed as correct by a system user, as well as words which have been predicted or hypothesized by the system during the recognition process.

"Word", as the term is used herein, may be a word or a phrase and may be spoken, written, or represented as electronic data signals. The term word may also encompass a tone, a character, punctuation symbols, numerals and any symbol expressive of one or more meanings such as an object, concept, condition, or action.

In one embodiment, the present invention includes word n-grams and category n-grams language models which can be selectively employed as additional sources of language knowledge. In one embodiment, the practice of this invention gets word and category n-gram knowledge by including appropriate short phrases among the selected sample passages. These short phrases are chosen if they contain a word or category n-gram which is shared by the current passage. With these short passages included in the selected set, it will be seen that n-gram like prediction can automatically become a part of the standard processing of this invention.

In another aspect, the invention provides methods and systems for simply and efficiently generating language knowledge, including generating lists of passages selected from one or more reference sources which can include a reference source that is accessed on-line. Accordingly, the present invention provides methods and systems for generating language knowledge in a form that allows portions of the language knowledge to be edited, adapted and updated independently from the other portions, thereby providing a context language model more easily updated to include new words, phrases or terms.

Additionally, the invention provides methods and systems for speech recognition, optical character recognition, machine translation, and other recognition applications. Word recognition methods and systems are described herein which serve to identify a word that occurs in a passage of words. The passage can be any word sequence including an utterance, a portion of handwritten text, a portion of typewritten text or other such sequence of words, phrases, numbers and characters.

In a further aspect, the invention is realized as a word recognition method that is implemented as a software module which controls a word recognition system that has access to an established reference source, such as a dictionary. The method can include a step of selecting from a reference source passages of words related to the choice words for the current word being recognized. To evaluate a choice word the method directs the system to access an established reference source, and select a passage or passages that contain language suitable to represent the semantic profile of the respective choice word. This semantic profile can represent the contexts, topics, themes and meanings that are associated with this choice word. For example, the choice word "car" can have a semantic profile that can include synonyms of the noun "car" such as "automobile" or "vehicle", as well as including words related to the topics associated with the word "car" such as "transportation" or "mechanic". In a further step, the system compares the words in the selected passages with the context words in the document or utterance containing the current word. Based on the comparison of the context words with the passage words, the method determines a probability signal or score that can indicate the likelihood that a choice word is the proper choice for the current word.

In one embodiment, the probability signal is generated by comparing the context words in the data string with the passage words associated with the choice word. The probability that a specific choice word is substantially similar to the current word being identified is increased if there is a

match between either the choice word or one of its associated passage words and one of the context words in the data string. A choice word can be selected from the list of possible choice words by comparing the probability signals and selecting the probability signal that indicates the highest probability that the associated choice word is substantially representative of the current word being recognized.

In a further practice, a list of passages is selected from a reference text, e.g., a dictionary or encyclopedia, having information related to the respective choice word or one or more words that have a known association with the choice word. In one practice the system can select words from a selected passage in a reference source by comparing each word in the passage against a stored list of words. The stored list can include words determined to be particularly likely to represent a meaning, a topic or a subject. These words are generally referred to as content words. Content words can be selected from the passage associated with the choice word and placed in the list as words representing a likely context for the choice word. In an alternative practice, the system can select words from a passage selected from a reference source by comparing each word in a reference source passage against a stored list of words representing words determined to lack a strong relationship to any particular meaning, subject or topic. These words are generally referred to as function words and can represent articles, prepositions or other words that are not likely to be closely associated with any particular topic or theme. All non-function words can be selected from the passage and placed in the list of passage words to represent the semantic profile of the choice word.

In various embodiments, the reference source can be a dictionary, an encyclopedia, a thesaurus, an antonym dictionary, a medical dictionary, a legal dictionary, an on-line computer database or any suitable reference source that contains information related to the choice word, and that is preferably indexed in a manner that allows ready access to the relevant information. In one typical example, the reference source is a conventional dictionary that includes discrete passages of information, where each passage is indexed by a head word. The system can employ the head word as a relevance indicator, i.e., an indication as to whether the passage is a relevant source of language knowledge.

In a further embodiment of the invention, the reference source can include training lists that include a relevance indicator such as a single word and one or more words which have been shown, preferably by statistical analysis, to have an association with the relevance indicator. These training lists can be developed by any of the common n-gram language models including bi-gram and tri-gram models as well as long context models.

In a further embodiment of the invention, the choice words in a choice list are selected from a vocabulary list that represents a list of known words employed by the recognition system or method. In a discrete word recognition embodiment, the recognition system selects choice words from the vocabulary list by comparing each word in the vocabulary list to the current word being recognized and selecting from the vocabulary list those words that are most similar to the current word. The vocabulary list can include a list of specialized terms and phrases relevant to a particular topic such as medicine, law or other such topics. The comparison between the words in the vocabulary list and the current word can include a step of comparing acoustic characteristics of the current word being identified with an acoustic model of the vocabulary word to generate a signal that represents the acoustic similarity between the current word and the acoustic model of the vocabulary word. Alternatively, the step of comparing can include a step of analyzing an image of the current word to recognize pattern characteristics of the word and comparing the identified pattern characteristics against known models of pattern characteristics associated to the words in the vocabulary list. In other embodiments, the language characteristics of words in the vocabulary list can be examined to select choice words having language characteristics that match the language characteristics of the current word, such as selecting vocabulary words identified as adjectives or verbs.

In a further embodiment, the invention includes word recognition systems that include a word list generator that generates a list of passage words for one or more of the context words in the current passage. The word recognition system further includes a choice list generator for generating a list of choice words. A correlation element correlates the passage words with the choice words, and generates a correlation signal for one or more of the choice words. The correlation signal can represent the likelihood that the associated choice word is contextually related to the context words and to the current passage and is a proper choice for the current word being analyzed.

The invention will next be described in connection with certain embodiments; however, it will be clear to those skilled in the art of word recognition that various modifications, additions and subtractions can be made to the below described embodiments without the departing from the spirit or scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more evident upon reading the following description of certain preferred embodiments in conjunction with the accompanying drawings, in which:

FIG. 1 is a functional block diagram of a recognition system according to the invention that selects a passage from a reference source to recognize an ambiguous word in a passage of words being analyzed;

FIG. 2 is a functional block diagram of a speech recognition system according to the invention;

FIG. 3 is a functional block diagram of a word recognition system according to the invention that includes a word list generator that provides a list of passage words for each context word in the current passage being analyzed and for each choice word in a choice list;

FIG. 4 is a functional block diagram of a word recognition system according to the invention that includes a word list generator that provides a list of passage words for each context word in the current passage being analyzed; and

FIG. 5 is a functional block diagram of a database search system according to the invention that includes a word list generator for expanding a list of keywords to include words related to the contexts of the keywords.

DETAILED DESCRIPTION

FIG. 1 is a functional block diagram that illustrates a word recognition system **10** according to one embodiment of the invention. The system **10** includes a memory element **12**, a choice list generator **14**, a word list generator **16** and a data processor **26**. Generally, the illustrated system **10** is a word recognition system that employs context recognition to recognize unknown words. The illustrated system **10** is adapted to recognize printed text and includes a scanning device for recognizing printed text, whether hand writing or

type-face, other embodiments, described herein are adapted to function as continuous speech or a discrete speech word recognition systems.

The illustrated system **10** operates on words stored in the data string memory **12** which includes one or more context words **36** and at least one unrecognized, or ambiguous, word **38** which is currently being recognized by the system **10**. The data string in the memory element **12** can represent the current passage of words being recognized by the system **10**. The choice list generator **14** couples to the data string memory **12** and generates a plurality of choice words **20**. The system **10** offers the list of choice words **20**, as possible substitutes for the current word **38** being analyzed by the system **10**. Optionally, the choice list generator **14** generates for each choice word **20** an associated probability signal **32** that indicates the likelihood that the choice word **20** represents the current word **38** being recognized.

In the illustrated embodiment, the word list generator **16** connects via a transmission path to a reference database **40**. The reference database **40** can be electronic memory that stores passages of text in an addressable format which typically includes a relevance indicator, such as a dictionary head word, that provides entry point information for the word list generator **16**. As will be explained in greater detail hereinafter, the word list generator **16** can employ the relevance indictor to select from the reference source **40** passages of text that are semantically relevant to one of the choice words **20**. In one embodiment, the word list generator **16** selects individual words, passage words **24**, to generate the lists of words **24A–24E**. Each list of words **24A–24E**, as will be explained in greater detail hereinafter, is a list of words that are likely to be seen or heard in association with the respective choice word **20**. In an optional embodiment, the word list generator **16** adds word and category n-gram knowledge by including appropriate short phrases among the selected sample passages. These short phrases are chosen if they contain a word or category n-gram which is shared by the current passage. Accordingly, the invention includes n-gram like prediction capabilities automatically as a part of the standard processing of this optional embodiment.

The word list generator **16**, depicted in FIG. **1**, is one particular and optional embodiment of a passage list generator that can connect to the reference database **40** to identify passages of language knowledge which are semantically relevant to an associated choice word, or in other embodiments, context words. The passage list generator can employ relevance indicators to select from the reference source **40** passages of text that are semantically relevant to one of the choice words **20**. For example, the passage list generator can connect to a reference database **40** that includes a dictionary. The passage list generator can select passages from the dictionary by comparing the choice words **20** to the dictionary headwords. Passages that have headwords that match, or substantially match, a choice word, are selected as a passage of text that is related to the matched choice word **20**. The passage list generator can select the indicated passages as sources of relevant language knowledge and can each entire passage as a passage that is associated with the respective choice word. In this way, the passage list generator can identify, select, and store a relevant passage of text for comparing with the context words in the data string. It will be apparent to one of ordinary skill in the art that a selected passage can be stored as a list of words, an array of words, a pointer to an array of characters, or any other technique suitable for storing a passage of text. It will also be apparent to one of ordinary skill in the art, that the technique for storing the passage can depend on the application, and the information, such as word order, that is desired to be stored and analyzed.

The data processor **26** can couple to the data string memory **12** and the word list generator **16** to operate on the words in the data string memory **12** and in the word list memories **22A–22E** to generate for one or more of the choice words **20A–20E** a probability signal **28A–28E** and an optional rank signal **30A–30E** that ranks the choice words **20A–20E** according to the likelihood of representing the current word **38** currently being recognized.

The system **10** illustrated in FIG. **1** is an optical character word recognition system according to the invention. The illustrated system **10** includes an optional document scanner unit **42** and an optional video monitor **44**. Both the scanner **42** and the video monitor **44** can be conventional and commercially available units such as the types commonly used for scanning documents into a computer system and for displaying the scanned contents to a user. One such scanner is the AVR 3000, manufactured by AVR Technology of San Jose, California. The scanner **42** can further include, or connect to, a processor unit operating a conventional word recognition system that operates on each word in isolation from the other words in the document (not shown) for translating the received serial data into binary codes representative of letters, words and numbers. These codes can be stored as context words **36** in the data string memory **12**.

The monitor **44** displays information to the system user. The information can include a visual representation of the words being analyzed as well as the list of choice words **20A–20E** being analyzed by the system **10**. However, the monitor element **44** can display additional information, such as system commands, the reference sources being employed to generate the word lists and other information. The monitor **44** can also include an audio element for providing audio representations of the information being displayed, thereby providing information to the visually impaired. Other display elements can be employed as the application demands, without departing from the scope of the invention.

The data string memory **12** can, in one embodiment, be a circuit card assembly of an electronic digital data random access memory that includes a serial interface for connecting to the optional scanner **42**, for receiving serial data from the scanner **42**. Alternatively, the data memory can be a hard disk memory, floppy disk memory, read only memory, optical disk memory, or other memory capable of storing electrical data signals representative of words and information.

The data string stored in memory **12** is a word sequence that includes one or more context words **36** and at least one current word **38** currently being recognized. Each context word **36** in the data string memory **12** is a symbol for expressing an object, action or condition. Furthermore, each word **36** can be a symbol for expressing punctuation, identification, quantity, musical notation and similar meanings that can be expressed, either visually, acoustically or otherwise, as a symbol. Each context word **36** is a symbol occurring in the data string stored in memory **12** that is associated with a word model employed by the recognition system **10**. Word models are well known in the art of word recognition, and any of the techniques for modeling a word, including acoustic models, character pattern models and so on, can be practiced with the present invention.

Similarly, each current word **38** is a symbol or a sequence of symbols occurring in the data string stored in memory **12** that is not associated, or not confidently associated, with any word model or sequence of word models employed by the

recognition system **10**. The system **10** can detect the current word **38** by comparing the known word models to the current word **38** using any of the known methods for detecting unknown words in a data string, including spell checking against a dictionary.

The data string in memory **12** can be any data signal representative of a sequence or passage of words. The current word **38** being recognized can occur at the beginning, the end or in the middle of the data string in memory **12**. The system **10** can optionally and selectively use the context words **36** that occur in the data string before or after the current word **38** to identify the current word **38**. Additionally, as will be explained in greater detail hereinafter, the system **10** can use the context words **36** that occur in the data string in memory **12** within a select window of time or within a select number of words for identifying the current word **38**.

Similarly, the choice list generator **14** can be a circuit card assembly that has a computer bus interface **46** for coupling via a computer bus transmission pathway to the data string memory **12**. The computer interface element **46** can be a standard parallel computer bus interface for transmitting data between the generator **14** and the memory element **12**. The choice list generator **14** can further include a processor unit **48** and a vocabulary memory **50**. The processor unit **48** can connect via transmission lines to the computer interface **46**, the vocabulary memory **50** and the choice list memory **18**. The processor **48** can be a conventional data processing unit of the type commonly employed in data processing devices and can include a central processing unit and a program memory. The processing unit **48** can receive context words **36** via the computer interface **46** and can select from the vocabulary memory **50** words related to the word **36**. The vocabulary memory **50** can be a conventional memory device of the type commonly employed in data processing devices. Such memory devices include random access memory cards, floppy disks, and optical storage memories.

In one embodiment of the invention, the processor **48** can store the entire stored vocabulary into the choice list memory **18**. For example, in a limited vocabulary word recognition system, such as a system for dialing a telephone or for entering commands into a computer, the choice list generator **14** can offer as choices all the words employed by the recognition system by storing all the vocabulary words in a choice list memory **18** of sufficient size.

Similarly, the word list generator **16** can be a circuit card assembly having a computer interface for coupling via a computer bus to the choice list generator **14**. The word list generator **16** can include a processing element such as the type previously described, and can have computer interface for coupling to the database **40**. The word list memories **22A–22E** can be memory units of the type previously described. The database **40**, as will be explained in greater detail hereinafter, can be an electronically operated addressable memory of the type used for storing large volumes of data, in either a compressed or non-compressed format. In the illustrated embodiment, the word list generator **16** has a separate word list memory **22A–22E** for each choice word **20A–20E**. Each illustrated word list memory **22A–22E** has five memory locations for storing five words **24A–24E**. Each word **24A–24E** in each word list memory **22A–22E** is part of the semantic profile of one of the respective choice words **20A–20E**. It should be apparent to one of ordinary skill in the art of computer engineering that other memory configurations and sizes, including dynamically varying memories can be practiced with the present invention without departing from the scope thereof. The data processor **26** can be a circuit card assembly that can include computer interfaces for coupling via a computer bus to the data string memory **12** and the word list generator **16**.

It will be apparent to one of ordinary skill in the art of word recognition that each card assembly described above can be realized as a software module for operation on a conventional data processing system and that such an implementation can be achieved without departing from the scope of the invention.

In one operation, the system **10** generates the list of words **24** and compares, as will be explained in greater detail hereinafter, the words **24** with the context words **36** in the data string memory **12**. In this illustrative embodiment, the system **10** employs a context recognition process to select a choice word. In other preferred embodiments that will be explained in greater detail hereinafter, the context recognition process is employed as part of a word recognition process that includes additional recognition procedures, such as acoustic modeling and character recognition. The data processor **26** can use the similarity between the words **24** and the words **36** in the data string memory **12** to select the choice word **20** that most likely represents the current word **38** being recognized. The system **10** can generate for the current word **38** a choice list **18** of known words **20A–20D** that could be written into the data string memory **12** to represent the current word **38**. As each choice word **20** represents a possible solution, the system **10** disambiguates between the possible solutions by generating the lists **22A–22E** and comparing the related words **24A–24E** for each choice word **20A–20E** to the context words **36** in the data string memory **12**. The occurrence of context words **36** in the data string memory **12** that are similar to one or more words **24**, indicates a choice word **20** that is associated with the context of the passage stored in the memory **12**. The illustrated system **10** can select the choice word **20** that is most closely associated to the context of the string stored in the memory **12** to represent the current word **38** being recognized.

As further illustrated by FIG. **1**, the system **10** can select a choice word **20** as a function of the context of the data string in memory **12** and the data in context list memory **22**. Each word **24** can represent a word that has a known relationship to the associated choice word **20**. The depicted data processor **26** generates as a function of the data string in memory **12** and the data in the word list memory **22**, a probability signal **28** that represents the likelihood that the associated choice word **20** is substantially representative of the current word **38**. Additionally, the system **10** can rank the choice words **20** as a function of the probability signal **28** and generate a rank signal **30** that represents the likelihood, relative to the other choice words **20**, that the associated choice word **20** is substantially representative of the current word **38** being recognized. As further illustrated by FIG. **1**, the data processor **26** can connect via a bi-directional pathway to the memory **12** for replacing the current word **38** with the selected choice word **20**. The selected choice word **20** can be substituted into the data string stored in memory **12** and employed by the word recognition system **10** as a context word **36**, or sequence of context words, that makes up part of the context associated with any other current words **38** to be identified by the system **10**. The monitor **44** can display the data string in memory **12**, including the choice word **20** substituted into the data string **12** to replace the current word **38**.

As depicted in FIG. **1**, the choice list generator **16** can generate for each current word **38** a list of one or more

choice words **20**. Each choice word **20** is associated with a word model or sequence of word models and represents a symbol or sequence or symbols that can be substituted into the data string in memory **12** for the current word **38**. The word list generator **16** generates a word list for each choice word **20** by storing in the associated word list memory **22** words **24** that together can represent a semantic profile for the associated choice word **20**. The data processor **26** can compare the words **24** of the semantic profiles against the context words **36**, to select the choice word **20** that best represents the word **38**.

In the character recognition embodiment illustrated in FIG. **1**, the current word **38** can be a partially recognized word having one or more recognized characters, such as letters. For example, the current word **38** could have an unrecognized first character succeeded by the recognized letter string "ORSE."

The current word **38** being recognized can be transferred via the bus interface **48** to the processing unit **48**. The processing unit **48** can, in one example, analyze the known information about the current word **38** to select choice words **20A–20E** from the vocabulary memory **50**. Continuing with the above example of an current word **38** having the letter string "ORSE," the choice list generator **14**, can match the identified string with stored vocabulary words. The word **38** could, for example, be associated with any of the vocabulary words gorse, horse, norse, morse, or worse, stored in the vocabulary memory **50**. Each of these five vocabulary words can be one of the respective choice words **20A–20E** stored by the processor unit **48** in the choice list memory **18**.

Alternatively, the choice list generator **14** can select the choice words **20A–20E** as a function of a static language model. In one embodiment the choice list generator can employ a uni-gram model to select choice words **20** as a function of their rate of occurrence in the English language. Each choice word **20** is associated with probability signal **32**. The probability signal **32** can represent the fact that not all words are used with the same frequency in a given language, and in fact, some words are used much more commonly than others. The probability signal **32** can represent a probability distribution related to the likelihood that the associated choice word **20** would normally occur in a word sequence such as the data string in memory **12**. The system **10** can generate a probability signal **32** for one or more of the choice words **20** by any of the statistical analytical techniques known in the art of language modeling. In this example, the system **10** employs a uni-gram language model that analyzes extensive amounts of training data, and measures, for each word in the language, the number of times the word occurs in the analyzed training data. Other language models, including the bi-gram and tri-gram models, can be used to generate the occurrence signals **32** and practiced with the depicted recognition system **10**.

Alternatively and preferably, the probability signal **28** and additional probability information are employed by the data processor **26** to generate a signal that represents the overall likelihood that the choice word **20** is substantially similar to the current ambiguous word **38**. In particular the data processor **26** can generate the signal as a function of the probability signal **28** and the probability signal **32**. In one practice, a tuning procedure is employed to develop a set of weighted coefficients that the data processor **26** employs to combine the signals **28** and **32** and generate a combined signal that represents the likelihood that the associated choice word **20** represents the current word. Such a combined signal takes into consideration the acoustic characteristics of the current ambiguous word **38** and the context characteristics of the current ambiguous word **38**. The data processor **26** can have a program memory that includes program instructions for generating the probability signal as a function of the two probability signals **28** and **32**. Techniques for generating the probability signal given two constraints, the probability signal **28** and the probability signal **32** are well known in the field of mathematics and any of the techniques capable of generating a probability signal given a set of constraints, including the maximum entropy technique, can be practiced with the present invention without departing from the scope thereof. The processor **26** employs the probability signal to generate the rank signal **30**.

Alternatively, the choice list generator **14** employs a long context language model that computes a probability signal **32** for each of the choice words **20A–20E** as a function of the surrounding words in the data string stored in memory **12**. Generally, context can be modeled by the context words **36** and the order of these words **36** in the data string in memory **12**. The selection of surrounding words **36** that can make up the context depends on the application. For example, in a document the context can comprise all the current words **36** that precede and follow the current word **38** being identified. In a real-time speech recognition system, the context can be modeled from the words **36** in the utterance that precede the current word **38** being identified. A speech recognition system, employing a long context model can use these available words to generate the list of choice words.

In another embodiment of the invention, the system **10** employs a context window **34** that selects a particular set of the context words **36** in the data string stored in memory **12** and employs this selected set during the recognition process. In the embodiment, illustrated in FIG. **1**, the choice list generator **14** places the context window **34** around the k words preceding the current word **38** being recognized. However, in alternative embodiments, the context window **34** can select the k words that follow the word **38** or the k words that surround the word **38**. Other sets of words can be selected, such as words at the beginning of paragraphs that are relevant to the context of the data string in the memory **12** and the word **38**, without departing from the scope of the invention. It should be apparent that k can be any integer number and its value depends on the application. For example, the long context model can employ long strings of data, for which an appropriate k value can range from 100–2000.

With reference again to FIG. **1**, the depicted word list generator **16** can be explained. As discussed above, for each choice word **20A–20E**, an associated word list **22A–22E** can model the likely contexts in which the choice word **20** would occur. The word list generator **16** can generate words **24** for storing in the word list memory **22** and the system **10** can compare the words **24** with the context words **36** and determine the likelihood that the word **20** represents the current word **38** currently being recognized.

The word list generator **16** can generate data for storing in the word list memory **22** by selecting words **24** that have a semantic association with the choice word **20**. In one embodiment, the word list generator **16** employs a heuristic approach to select words **24**. In a first step, the generator **16** selects a reference source **40** containing sample passages of raw text, i.e., language information, and data that are relevant to the corresponding choice word **20**. Typically, the reference source **40** includes relevance indicators for each sample passage. Typical relevance indicators include dictionary and encyclopedia headwords, or the keyword lists

associated with magazine and journal articles. The word list generator **16** can identify the contextually relevant sample passages by comparing the relevance indicators to the word being analyzed.

The reference database **40** can be a dictionary, thesaurus, antonym dictionary, medical dictionary, legal dictionary, scientific and engineering dictionary, or other type of reference source. Typically, the source **40** is one or more existing reference sources that include headword relevance indicators. However, it should be apparent to one of ordinary skill in the art that any database can be readily indexed by word to thereby create reference database **40** particularly suited for use with the invention. Such indexing programs include the program ZY Index manufactured by the company ZY Lab.

In one example, the generator **16** connects to a dictionary reference source **40**. The dictionary reference source **40** can be a conventional software dictionary reference that includes discrete passages of text, with each passage indexed by a head word. Typically, each discrete passage represents a dictionary definition of the associated head word. The system **10** employs the head word as a relevance indicator which indicates whether the discrete passage contains information relevant to the choice word. The generator **16** selects passage words from one or more sample passages associated with a respective choice word **20**. The selected passage words represent words that are likely to be semantically related to the respective choice word **20**. Therefore, the semantics of the selected passage words **24** model the contexts that are likely to be expressed in a window **34** that surrounds the current word **38**.

In one preferred embodiment of the invention, the reference source **40** comprises an on-line electronic database that is word indexed for addressably accessing subtopics of information. For example, a word recognition system **10** could maintain on-line the GROLIER'S ENCYCLOPEDIA sold by the Grolier's Electronic Publishing. The word list generator **16** can access interactively the encyclopedia passages related to the choice word **20**. The word list generator **16** can select passage words from the selected encyclopedia passages semantically related to the choice word **20**. For example, the generator **16** can select every content word in the first three sentences of a selected encyclopedia passage. A content word, as is generally known in the field of word recognition, is a non-function word, and can be a noun, verb or adjective. These words are generally considered in the field of word recognition to be more meaningful to context than function words, such as pronouns, articles and prepositions.

One important aspect of the invention is that the reference source **40** employed by the system **10** can contain information recorded in a different language from the language of the words being recognized. For example, the system **10** can be adapted for recognizing words in the Greek language. As described above, text can be scanned in by the scanner element **42** and context words **36** in the Greek language can be stored in the data memory **12** while current words **38** are processed by the system **10**. As described above, the choice list generator **14** can generate for each current word **38** a list of choice words **20A–20E**. The word list generator **16** can generate a context list **22** for each choice word **20A–20E**. In one embodiment of the invention, the word list generator **16** can be adapted for accessing a reference database having information in the English language. For example, each choice word **20A–20E** can be transmitted to the word list generator **16**, which includes a conventional translation unit, so that an English language translation of each of the choice words **20A–20E** can be generated by the word list generator using any of the known translation techniques, including bi-lingual dictionary databases, bi-lingual concordance lists and bi-lingual dictionaries produced by aligning text automatically. One such bi-lingual dictionary is described in the publication Brown et al., "*A Statistical Approach to Machine Translation*", Computational Linguistics, Vol. 16, No. 2, p 79–85 (1991).

The English language translation of each choice word **20** can be employed by the word list generator **16** to access the reference database **40** of information recorded in the English language. For example, the reference database **40** can be an English language version of the Encyclopedia Britainica. Alternatively, the reference database **40** can be a source of information, such as a database of English language patents, that may not be available in the native language of the document being analyzed.

As described above, the word list generator can select a plurality of passage words **24A–24E** from the English language reference source **40** and can store the passage words **24A–24E** in a word list memory **22A–22E**. The word list generator **16** can then translate each of the English language passage words into a native language equivalent, such as a Greek language equivalent. The system **10** can continue as described above by comparing the translated passage words **24A–24E** with the native language words **36** stored in the data memory **12**. It should therefore be apparent to one of ordinary skill in the art of speech recognition, that the invention provides a system that includes semantic profiles of select words, and that these semantic profiles transcend the native language of the document being recognized. Therefore, the invention can employ reference sources that include, in part or in whole, information recorded in a language, or several languages, different from the language of the words being recognized.

The lack of sufficient native language reference information can also be addressed by an alternative embodiment of the word list generator **16** that includes a language model element adapted to generate a list of words strongly related to the context of the choice word **20**. One model, previously described, can be the long context language model, for generating a list of words **24** shown to be strongly related to the choice word **20**. In an off-line step, the long context model can analyze training data to develop for each word in the vocabulary a training list of strongly related words. The word list generator **16** can select these words, or a portion of these words, to represent the stored words **24**. The short lists can be employed in a system that recognizes words in the same language, or can be translated using any of the known techniques, into a different language for use with a system that recognizes words in a different language from the native language of the developed context lists.

The data processor **26** can generate the probability signal **28** as a function of the data string in the memory **12** and the data in the word lists memory **22**. In one embodiment, the processor **26** compares and generates the probability signal **28** as a function of the co-occurrence of words stored in the list memory **22** and the data string in the memory **12**. The probability signal can be generated by counting the number of matches between distinct words in the word list and distinct context words. For example, if the word HORSE appears as a context word **36**, then the occurence, any number of times, of the word HORSE in a passage generates a word count of one. A choice word that is associated with passages that include many of the context words, is probably a good choice. Alternatively, each matched word can be weighted by a frequency count representative of the fre-

quency with which it occurs in the selected passage or by the frequency with which it occurs as a context word **36**. Additionally, the significance of each word match between a context word **36** and a word in a passage can be weighted by the word distance between the context word and the choice word **20** associated with the passage. Moreover, the system can weight the matched words as a function of whether the matched words are content words or function words. Furthermore, the probability signal can be adjusted upon detection of matching n-grams between a series of context words and a series of passage words. However, it will be apparent to one of ordinary skill in the art of word recognition that many known techniques can be employed to generate the probability signal **28**. Any of these methods, or variations thereof, can be used without departing from the scope of the present invention.

In an optional step, the data processor **26** can order the choice words **20** as a function of the probability signal **28**, and generate a rank signal **30** that identifies the order of each choice word **20A–20E**. The choice words **20A–20E**, can be displayed as a menu of choices on the optional monitor **44**. The operator of the word recognition system **10** can select a choice word **20** from the menu to confirm a substitute for the current word **38** being recognized. Alternatively, the word recognition system **10** can select the choice word **20** with the highest probability signal **28** or rank signal **30** to substitute for the current word **38** currently being recognized. In a preferred yet optional embodiment, the data processor **26** stores a user-selected probability threshold signal that represents a probability indicating sufficient confidence that the choice word **20** represents the current word **38** being recognized. The processor **26** can automatically select the choice word **20** having the highest probability signal **28** over the user-selected threshold. Alternatively, the processor **26** can display a menu of the choice words **20** to allow the user to select the choice word.

It should be readily understood to one of ordinary skill in the art of electrical engineering or computer science that system **10**, illustrated as a block diagram of components, can be readily constructed as a system of circuit card assemblies, software modules or a combination of both. In particular, the data string memory **12**, choice list generator **14**, word list generator **16** and data processor **26** can be constructed as a system of machine code and program instructions for operating a word recognition system employing known techniques in the art of computer engineering.

It should also be apparent, from the above description, that in a recognition application, the actual words used in the current passage are not known, but in fact are being estimated by the system. In a word-by-word interactive system, there will be a left to right asymmetry—the preceding context words have been confirmed by the user, but the following context words have only been guessed or estimated. More generally, even the preceding context words may be uncertain. When there is uncertainty about some of the context words in the current passage, the preferred embodiment will analyze multiple alternate hypotheses for the current passage. The total estimated probability for any choice word in a particular position will be the total probability assigned to that choice word in each hypothesis for the current passage summed over all alternate hypotheses for the current passage.

In FIG. 2, another embodiment of the present invention is shown, incorporating the word recognition system of the invention into a speech recognition system **60**. The system **60** can include a speech input device **62** for acquiring speech signals, an A/D converter unit **64** for converting the acquired speech signals into digital data signals, and a speech analysis unit **66**, for analyzing the speech signals and for recognizing, with a certain degree of probability, the words that make up the speech signals. Systems and methods for speech analysis that collect and analyze portions of speech are known and have been developed and described in patented publications by the assignee hereof. Such systems are described in U.S. Pat. No. 4,866,778, "Interactive Speech Recognition Apparatus", issued to James K. Baker and assigned to the assignee hereof. These and other speech recognition systems can be practiced with the present invention without departing from the scope thereof.

System **60** can detect words within portions of speech signals and compare these detected words to acoustic models of known words, or sequence of acoustic models of known words. The comparison leads to a probability signal that indicates the certainty that the detected word is substantially acoustically similar to the word associated with the acoustic model. A high degree of certainty indicates that the detected word has been recognized as the word associated with the corresponding acoustic model. The recognized word is presented as a context word **36** in the current passage stored in the data string memory **12**. Alternatively, a low degree of certainty indicates that the detected word has not been confidently identified. This unrecognized word is represented as the current word **38** in the data string memory **12**. The current word **38** is associated with a list of choice words **20A–20E**. The choice list **18** can store the words **20** associated with the acoustic models from the vocabulary memory **50** which are acoustically similar to the current ambiguous word **38** being identified. Each choice word **20A–20E** can have a corresponding acoustic probability signal **68A–68E** that represents the degree of certainty that the word **20** associated with the acoustic model is substantially representative of the current word **38** being recognized. Additionally, the probability signal **68A–68E** can represent the acoustic model probability adjusted by an n-gram probability, or any suitable language model.

The speech recognition system **60** depicted in FIG. **2** includes, in addition to the speech input device **62**, the A/D converter **64** and the speech analysis unit **66**, a data memory **12**, a choice list generator **14**, a word list generator **16**, a data processor **26**, an optional reference database **40**, and an optional monitor unit **44**. As illustrated in FIG. **2**, the memory **12** can connect via a transmission path to the speech analysis unit **66**. The memory **12** can receive analyzed speech data signals from unit **66** that represent the voice signals spoken into the input device **62**. The analyzed speech data signals can include context words **36** and current words **38**. The current words **38** can in this embodiment represent spoken words that contain insufficient information for the analysis unit **66** to determine, or determine with a sufficient level of confidence, a word model that can be associated with that word **38**. As further illustrated by FIG. **2**, the optional monitor **44** connects to the data memory **12** for displaying the data string of context words **36** and current words **38** stored in the memory **12**. The data memory **12** can connect via a transmission path to a computer interface **46** in the choice list generator **14**. The choice list generator **14** can contain choice list memory **18**, a processor **48** and a vocabulary memory **50**.

The word list generator **16** can connect via a transmission path to the choice list generator **14** and can connect to an optional reference database **40** via a second transmission path. The word list generator **16** can have word list memories **22** each having storage elements **24** for storing a word.

The data processor **26** can connect via a transmission path to the word list generator **16** and via a transmission path to

the data memory 12. The data processor 26 can generate a probability signal 28 representative of the likelihood that one of the choice words 20 substantially representative of the current ambiguous word 38 and the memory 12. Optionally the data processor 26 can generate a rank signal 30 representative of the probability as a function of the acoustic language model and the context model that the choice word is representative of the current word 38.

In the embodiment depicted in FIG. 2, the choice list generator 14 can be a circuit card assembly that couples via a computer bus interface to the data string memory 12. As previously described with reference to FIG. 1, the choice list generator 14 can also include a computer interface element 46 for transmitting data between the choice list generator 14 and the memory element 12 via the computer bus. In the depicted embodiment the data memory 12 can store and transmit to the choice list generator 14 information regarding the acoustic characteristics of the current word 38. The choice list generator 14 can include a processor unit 48 and a vocabulary memory 50 constructed to operate on the acoustic characteristics of a word. The processor 48 and vocabulary memory 50 can be constructed according to any of the known techniques for recognizing a word from acoustic characteristics of a speech signal and for storing an acoustic model of a spoken word or sound.

The processor 48 can implement any of the known techniques for selecting from a vocabulary of word models, a set of word models or a sequence of word models likely to represent an unknown or current word. Such systems and methods are described in U.S. Pat. No. 5,027,406 titled "Method for Interactive Speech Recognition and Training" and U.S. Pat. No. 5,202,952, titled "Large-vocabulary Continuous Speech Prefiltering and Processing System", both of which are assigned to the assignee hereof and incorporated herein by reference. For example, the present invention can be practiced as part of a continuous speech recognition system, such as the systems described in the above-referenced U.S. Pat. No. 5,202,952. As described in greater detail therein, these systems can include a stored vocabulary of word models. Utterances spoken into the microphone are temporarily segmented, and at least two non-successive segments are processed with respect to the vocabulary. A subset of word models is selected from the stored vocabulary based on predetermined criteria. The subset of word models defines a list of candidate words which are representative by a signal generated by the system of the invention. The list of candidate words can be used as a list of choice words 20, by the present invention. Accordingly, a continuous speech recognition system employing the context recognition process of this invention represents multiple operations of discrete speech recognition taking place in parallel. For simplicity and clarity, only one operation is described herein.

To generate the list of choice words 20 from a continuous speech utterance, the invention, in one form, generates a succession of frame data sets which begin at a frame start time. Each of the frame data sets represents successive acoustic segments of utterances for a specified frame period. The system also includes a vocabulary, trained into the system by the operator, which may be stored within the system as clusters. Each cluster includes a plurality of word models which are acoustically similar over a succession of frame periods. Each word model includes nodes representing the probability distribution for the occurrence of a selected acoustic segment from that word model in a segment of the speech to be recognized.

The system generates a cluster score which represents the likelihood whether the frames represent words in that word cluster. Cluster sets having cluster scores above a predetermined acoustic threshold are removed from further consideration.

The remaining cluster sets are then unpacked to identify the individual words from each identified cluster. At this point, the system can generate a word score for each unpacked word resulting from the first filter. The word score can, in one practice, represent the sum of the cluster score for the cluster from which the word was unpacked, and a static language model score generated by the above described method and system. This word score is used to identify those words which are below a second combined threshold to form a list of choice words 20. Preferably, the system generates a list of the best segmentation hypotheses, an N best list, and applies the context recognition scheme only to those hypotheses that have an acceptable likelihood of success. The choice words generated by this embodiment can represent phrases of one or more words. These choice phrases represent candidate word sequences which may represent the utterance being analyzed. Moreover, in this embodiment, the current word being analyzed in actually an utterance of speech which can represent one or more words. The choice list 20 generated by the system is a list of phrases that is sent to the data processor 26 for analysis by the context model system and method of the present invention. Additionally, the choice list generator 14 can incorporate along with these acoustic model matching techniques, other techniques as were described with reference to FIG. 1, including language model techniques.

Each of the illustrated choice words 20A–20E can be stored in the choice list memory 18 that can be constructed as a data memory for storing electrical data signals representative of machine-readable data. Preferably yet optionally, each choice word 20 can be associated with a probability signal 68, illustrated in FIG. 2 as stored in the choice list memory 18 as signals 68A–68E. The probability signals 68A–68E can represent the likelihood that the associated choice word 20A–20E is substantially representative of the current word 38 currently being recognized. In one embodiment of the speech recognition system 60, the probability signal 68A–68E can be generated as a function of the acoustic properties of the current utterance 38 being analyzed and the acoustic properties of the word models stored in the vocabulary 50. Such techniques for generating this probability signal 68A–68E are described in the references cited above.

The word list generator 16 can also be constructed as a circuit card assembly having a computer interface for coupling via a computer bus to the choice list generator 14. As described with reference to FIG. 1, the word list generator 16 can include a processing element and can optionally connect to a reference database 40. The word list generator 16 can select passages from a reference source, and optionally generate context words 24 for storing in the word list memories 22A–22E. The word list generator 16 can access via a transmission path the reference database 40 and can identify information in the reference database 40 that relate to the topic, theme, or subject of a choice word 20. The word list generator 16 can select from this identified information, one or more words that can represent the words 24A–24E. In the illustrated embodiment, the word list generator 16 generates data to store in the word list memories 22A–22E having one or more words 24. It will be apparent to one of ordinary skill in the art that the word list generator 16 can be modified to generate word lists for only select choice words 20, and can be modified to generate data for the word list memories 22 that store a predetermined number of words 24

that have certain characteristics. Such characteristics can include distance, in time, or word sequence, of the context word **24** from the choice word **20** in the database, or the number of times the word **24** occurs within the reference database **40** in relation to the associated choice word **20**.

The reference database **40** can be an on-line database that is accessed by the word list generator **16** on the fly. Such databases include the Grolier's Encyclopedia previously described. Additionally, the reference database **40** can be a dictionary, thesaurus, antonym dictionary, medical dictionary, legal dictionary, scientific and engineering dictionary, or other type of reference source. Preferably the database **40** is addressable as a function of the choice word **20**, however it should be apparent to one of ordinary skill in the art that any database can be readily indexed by word, for generating a reference database **40** suitable for use with the present invention. Such indexing programs include the program ZY Index manufactured by the company ZY Lab.

The data processor **26** connects via transmission paths to the memory element **12** and the choice list generator **14**, and generates as a function of the context words in the memory element **12** and the passage words **24** in the word lists **22**, a probability signal **28** representative of the likelihood that the choice word or phrase **20** substantially represents the utterance currently being recognized. The data processor **26** as previously described can be a processing unit of the type commonly used for processing digital data signals. The processor **26** can include a processing unit and a program memory for executing program instructions to operate the processing unit to manipulate the data in memory element **12** and the data stored in the word list memories **22A–22E**. In one embodiment of the present invention, the data processor **26** performs a matching function to calculate the number of matched words between the context words **36** and the stored word or phrase **24**. The relative frequency of matches between the context words **36** and the passage words **24**, indicates the relative likelihood that the choice word or phrase **20** associated with the matched words **24**, is substantially representative of the current ambiguous word **38**. In one practice, the choice word **20** represents a phrase of one or more words that may represent the utterance being analyzed. The word list generator **16** can select relevant passages from the reference source **40** for each word in the choice phrase **20**. The data processor **26** can compare the context words **36** with all the passages for all the words in a particular choice phrase, to determine the likelihood that the choice phrase represents the utterance being analyzed.

Alternatively and preferably, the probability signal **28** and additional probability information are employed by the data processor **26** to generate a signal that represents the overall likelihood that the choice word **20** is substantially similar to the current ambiguous word **38**. In particular the data processor **26** can generate the signal as a function of the probability signal **28** and the probability signal **68**. In one practice, a tuning procedure is employed to develop a set of weighted coefficients that the data processor **26** employs to combine the signals **28** and **68** and generate a combined signal that represents the likelihood that the associated choice word **20** represents the current word. Such a combined signal takes into consideration the acoustic characteristics of the current ambiguous word **38** and the context characteristics of the current ambiguous word **38**. The data processor **26** can have a program memory that includes program instructions for generating the probability signal as a function of the two probability signals **28** and **68**. Techniques for generating the probability signal given two constraints, the probability signal **28** and the probability signal **68** are well known in the field of mathematics and any of the techniques capable of generating a probability signal given a set of constraints, including the maximum entropy technique, can be practiced with the present invention without departing from the scope thereof. The processor **26** employs the probability signal to generate the rank signal **30**.

FIG. **3** depicts an alternative embodiment of the invention that is a word recognition system **76** which includes the speech input device **62**, an A/D converter **64** and the speech analysis unit **66** depicted in FIG. **1**. Additionally, an optional monitor **44** connects to a data memory **78** and can display the context words **36** and the current words **38** stored in the memory **78**. The system **76** further includes a choice list generator **14** that includes a choice list memory **18** for storing choice words **20A–20E** and for optionally storing a probability signal **68A–68E**. The choice list generator **14** further includes the computer interface **46**, a processing unit **48** and a vocabulary memory **50**. System **76** further includes a word list generator **80** that has word list memories **22A–22E** for storing words **24**. The word list generator **80** connects to an optional reference database **40**, connects to the memory **78** and connects to a data processor **82**. The data processor **82** connects to the memory **78** and generates probability signals **28A–28E** and optionally **30** for each choice word **20** generated by the choice list generator **14**.

In the illustrated embodiment the memory element **78** connects via a transmission path to the speech analysis unit **68** and a via transmission path to the optional monitor **44**. As illustrated in FIG. **3**, the memory element **78** includes storage elements **84** that store for each context word **36** a list of words **86**. As further illustrated by FIG. **3** the memory element **78** connects via transmission paths to the list generator **80**. In the embodiment depicted, the word list generator **80** generates for each context word **36**, as previously described, list of passage words **86** that can be stored in the memory element **84** associated with a particular context word **36**. In a preferred embodiment of the invention the memory element **78** is a digital data random access memory for electronically addressably reading, writing and storing data. The memory element **78** can be a sequential memory having a first memory register bank for storing the context word **36** and having a second register bank **84** for storing the list of passage words **86** associated with the context word **36** in the first register bank. The memory element **78** can have a computer interface for connecting to a computer bus and for transmitting information to the computer interface **46** of the choice list generator **14**.

The choice list generator **14** can be constructed as previously described with reference to FIGS. **1** and **2**, for generating a list of choice words **20A–20E** that can be stored in choice list memory **18**. The choice list generator **14** can use language models, including the long context model, unigram, bi-gram, tri-gram and special language models as well as acoustic model matching, for selecting from the vocabulary memory **50** the choice words **20A–20E**. Additionally the processor element **48** of choice list generator **14** can generate a probability signal **68A–68E** representative of the likelihood that the choice word is substantially similar to the current ambiguous word **38** being recognized. The processor element **48** of choice list generator **14** can generate the signals **68A–68E** as a function of the acoustic model characteristics, language model characteristics, or combinations of both, according to known techniques in the art of probability statistics and word recognition.

The word list generator **80** connects via a transmission path, such as a computer interface, to the memory element **78** and optionally connects via a transmission path to the

reference database **40**. The word list generator **80** can operate as previously described to select words **24** for one or more of the choice words **20A–20E** and for storing these words in the word list memories **22**, each associated with a respective form of the choice word **20A–20E**.

The data processor **82** can include a processing element, such as a conventional data processing unit for processing digital data signals, that can generate probability signals **28A–28E** as a function of the context words **36**, the list of passage words **86** and passage words **24**. In one embodiment of the present invention, the data processor **82** generates the probability signals **28A–28E** by comparing the occurrence of passage words **24** within the data string that includes the context words **36** and the associated expanded list of context words **86**. In one embodiment, the data processor generates a passage count signal, for each choice word, that represents the number of passages of context words that include that choice word. The passge count can be employed by the data processor as a wieghting factor for generating the correlation signal. Other systems and methods for generating the probability signals **28A–28E** can be practiced with the invention without departing from the scope thereof. As explained with reference to FIG. **2** the data processor **82** optionally can generate a rank signal **30** that represents the likelihood, as a function of the context matching and acoustic model matching that a choice word **20** is substantially similar to the current word **38** currently being recognized.

In one alternative embodiment of the system depicted in FIG. **3**, a machine translation unit, as previously described, provides for each choice word **20** a list of passage words in a second language. Further, a machine translation unit, as previously described, provides for each context word, a list of passage words **86** in the second language. The data processor **26** can then perform the comparison by comparing passage words which are recorded in the second language.

FIG. **4** illustrates a further alternative embodiment of the present invention. The system **140** depicted in FIG. **4** is similar to the system **76** depicted in FIG. **3**, however, the system **140** of FIG. **4** includes a word list generator **142** that connects via transmission paths to the memory element **78** and that generates for each context word **36** in the memory element **78**, a list of words that can represent the semantic profile of the context word **36**. The expanded list of context words **86** can be stored in the memory elements **84** for use by the data processor element **144** that includes a processing element such as a conventional data processing unit for processing digital data signals and that is adapted to generate probability signals **28A–28E** as a function of the known words **36**, the list of words **86** and the choice words **20A–E**.

As depicted by FIG. **4**, the system **140** provides a word recognition system that employs context models of the context words **36** in a data string to select one of the choice words **20A–20E** generated by the choice list generator **14**. The data processor element **144** can include a program element that correlates the list of context words **86** with the choice words **20A–20E** to select the proper choice for the current ambiguous word **38**. As described above, the correlation between the words **86** and the choice words **20A–20E** can include a heuristic process that selects a choice word **20A–20E** by identifying occurrences of the selected choice word within one or more of the lists of words **86**. Other techniques for selecting one of the choice words **20A–20E** can be practiced with the present invention without departing from the scope thereof.

FIG. **5** illustrates an alternative embodiment of the invention. FIG. **5** illustrates a database search system **90** that includes a data memory **92** for storing key words **94**, a word list generator **96** for generating and storing in word list memory **98**, words **100**, and further includes a data processor **102** for searching a database **104** having a library of documents **106** wherein each document has optionally associated with it memory **108** for storing a probability signal. The system **90** further includes a document selection unit **110** for generating a file **112** of documents **114** having text **116** related to the keyword **94** or the context words **100**.

The keyword memory **92** depicted in FIG. **5** can be a conventional digital data random access memory for storing the keywords **94** as electronic digital data signals. The keywords **94** can represent words, phrases, numbers and punctuation marks or any other symbol suitable for expressing an idea, action or object. Keywords **94** can be entered into data memory **92** according to any conventional methods or storing information in a data memory, such as by keyboard data entry or by speech recognition. Each keyword **94** is a known word having a known association with a word model stored in a word vocabulary employed by the system **90**.

As illustrated in FIG. **5** the word list generator **96** connects via a transmission path to the data memory **92**. The word list generator **96** receives keywords **94** from data memory **92** and generates for each keyword **94** a list of words **100** that are stored in word list memories **98**. The word list generator **96** can include a processing unit in a vocabulary memory (not shown) as previously described with reference to FIG. **1**. The word list generator **96** can connect via transmission path to an optional reference database **40**. As previously described, the word list generator **96** can access the reference database **40** to select from information stored in the database **40**, and related to a respective one of the keywords **94**, a list of passage words **100**. As described with reference to the earlier embodiments of the invention, the word list generator **96** can select passage words **100** as a function of the proximity of the passage word **100** to the keyword **94** within the reference source **40**, as a function of the rate of occurrence of the passage word **100** within the information or related to the keyword **94**, as a function of the relative position of the passage word **100**, such as a topic sentence, or as a combination of these methods. Other methods for selecting the passage words **100** from the reference database **40** can be practiced with the present invention without departing from the scope thereof.

The data processor **102** connects via a transmission path to the word list generator **96**. The data processor **102** can be a conventional digital data processing unit for manipulating digital data signals representative of information. The data processor **102** can further include a program memory for storing a sequence of program instructions and a processing unit for operating according to the program instructions in the program memory. As illustrated in FIG. **5** the data processor **102** connects via a transmission path to the document library **104**. The data processor **102** can search the content of the documents **106** stored in library **104** and generate for each document **106** a probability signal **108** that the related document **106** contains information related to the keywords **94**. Preferably the data processor **102** is of the type capable of performing Boolean searches. Such systems are known in the art of database searching, and any such system can be practiced with the present invention without departing from the scope thereof.

As illustrated in FIG. **5** the system **90** further includes a document selector **110** that selects one or more documents **106** from the library **104**. The selector **110** connects via data

pathway to the library **104** and to the file **112** for storing in the file **112** a set of documents **114** likely to obtain information related to the keywords **94**. In one embodiment of the invention the selector **110** contains a processing unit having a user selected threshold signal stored in memory. The user selected threshold represents a confidence value for a probability signal that is stored in memory **108**. The selector **110** can select any document **106** that has an associated probability signal **108** greater than the confidence signal in memory stored in the memory of the selector unit **110**.

It will thus be seen that the invention efficiently obtains the objects set forth above, among those made apparent from the proceeding description. It will also be understood that changes may be made in the above construction and foregoing sequences and operations without departing from the scope of the invention. Accordingly, it is intended that all matters shown in the accompanying drawings be interpreted as illustrative rather than in any limiting sense. It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention as described herein, and all the statements of the scope of the invention which as a matter of language might be said to fall therebetween.

Having described the invention, what is claimed as new and secured by letters patent is:

1. A method for ascertaining an ambiguous word that occurs in a data string which includes at least one context word, comprising the steps of

generating a list of one or more choice words to represent choices for the ambiguous word,

providing a reference source having one or more passages, each passage including a relevance indicator and a series of words associated with the relevance indicator,

selecting as a function of one of said choice words and said relevance indicators, at least one of said passages from said reference source,

generating one or more correlation signals, as a function of said one or more selected passages, and at least one of said context words, to represent the likelihood that said choice word is a match for the ambiguous word, and

selecting, as a function of said one or more correlation signals, at least one of said choice words to represent the ambiguous word being identified.

2. A method according to claim **1** for use with a continuous speech recognition system, wherein

said step of generating said list of choice words, includes the steps of comparing select characteristics of a portion of speech to one or more word models each being representative of a word in a vocabulary, and

selecting as a function of said comparison a subset of said words from said vocabulary.

3. The method according to claim **1** wherein said step of generating said correlation signals includes the further step of

generating a list of passage words representative of one or more of the content words in said selected passages.

4. A method according to claim **1** wherein said step of providing a reference source includes the step of

providing a reference source comprising a dictionary.

5. A method according to claim **1** wherein said step of providing a reference source includes the step of

providing a reference source comprising an encyclopedia.

6. A method according to claim **1** wherein said step of selecting passages includes the step of

selecting a choice word in a first language,

translating said selected choice word into a second language,

accessing a reference source comprising information recorded in the second language and selecting said passages therefrom, and

translating said selected passages into the first language.

7. A method according to claim **1** wherein the step of selecting passages from a reference source includes the step of

comparing the choice word with the relevance indicators, and selecting passages having a relevance indicator that contains a word that substantially matches the choice word.

8. A method according to claim **1** wherein the step of generating said correlation signals includes the step of

determining, for each choice word, a word count representative of the number of distinct words in the associated passages that match with one of the context words in the data string and generating said correlation signal as a function of said word count.

9. A method according to claim **8** wherein said step of generating said correlation signals includes the further step of

determining a frequency count for each passage word representative of the number of times the passage word occurs in a passage, and

generating said correlation signals as function of said word count weighted by said frequency count.

10. A method according to claim **1** wherein said step of generating correlation signals includes the further steps of

generating an occurrence signal for each of said choice words as a function of an n-gram language model and one or more of said context words to represent the likelihood that said choice word would be selected from a set of vocabulary words, and

combining said occurrence signal with said correlation signal, representative of the likelihood that said choice word is a match for the ambiguous word, to adjust said correlation signal as a function of said likelihood of occurrence for said choice word.

11. A method according to claim **1** wherein said step of generating said correlation signals includes the step of

adjusting each of said correlation signals as a function of a word count signal representative of the number of words separating a matching context word from the ambiguous word being recognized.

12. A method according to claim **1** wherein the step of generating the correlation signals includes the step of comparing the selected passages with the context words to detect a matching n-gram.

13. A method for ascertaining an ambiguous word that occurs in a data string that includes one or more context words, comprising the steps of

generating a list of one or more choice words to represent choices for the ambiguous word,

providing a reference source having one or more passages each of which includes a relevance indicator and a series of passage words associated with the relevance indicator,

selecting as a function of each of said relevance indicators and said context words, at least one passage from said reference source for at least one of said context words,

generating a correlation signal for each of said choice words as a function of said passages and said choice

words, to represent the likelihood that a respective choice word is a match for the ambiguous word, and

selecting as a function of said correlation signals, at least one of said choice words to represent said ambiguous word.

14. A method according to claim 13 for use with a continuous speech recognition system, wherein

said step of generating said list of choice words, includes the steps of comparing select characteristics of a portion of speech to one or more word models each being representative of a word in a vocabulary, and

selecting as a function of said comparison a subset of said words from said vocabulary.

15. The method according to claim 13 wherein said step of generating said correlation signal includes the further step of

generating a list of passage words representative of one or more of the content words in said passage.

16. A method according to claim 13 wherein said step of selecting one or more passages includes the step of

providing a reference source comprising a dictionary.

17. A method according to claim 13 wherein said step of selecting one or more passages includes the step of

providing a reference source comprising an encyclopedia.

18. A method according to claim 13 wherein said step of selecting one or more passages includes the steps of

selecting a context word in a first language,

translating said selected context word into a second language,

accessing a reference source comprising information recorded in the second language and selecting said one or more passages therefrom, and

translating said selected passages into the first language.

19. A method according to claim 13 wherein the step of selecting passages from a reference source includes the step of

comparing the context word with each of the relevance indicators, and selecting passages having a relevance indicator that contains a word that substantially matches the context word.

20. A method according to claim 13 wherein the step of generating said correlation signals includes the step of

determining, for each choice word, a passage count representative of the number of context words having a passage that includes a word that matches the choice word and generating each said correlation signal, representative of the likelihood that said choice word is a match for the ambiguous word, as a function of said passage count.

21. A method according to claim 20 wherein said step of generating said correlation signal includes the further step of

determining a frequency count for each choice word representative of the number of times the choice word occurs in the passages, and

generating each said correlation signal as function of said passage count weighted by said frequency count.

22. A method according to claim 13 wherein said step of generating correlation signal includes the further steps of

generating an occurrence signal for each of said choice words as a function of an n-gram language model and one or more of said context words to represent the likelihood that said choice word would be selected from a vocabulary of words, and

combining said occurrence signal with said correlation signal, representative of the likelihood that said choice word is a match for the ambiguous word, to adjust said correlation signal as a function of said likelihood of occurrence for said choice word.

23. A method according to claim 13 wherein the step of generating said correlation signal includes the step of

adjusting said correlation signal as a function of a word count signal representative of the number of words separating the ambiguous word from a context word having a passage that contains a word that matches the choice word.

24. A method for ascertaining an ambiguous word that occurs in a data string which includes one or more context words, comprising the steps of

generating a list of one or more choice words to represent choices for said ambiguous word,

providing a reference source having one or more passages, each passage including a relevance indicator and a series of passage words associated with the relevance indicator,

comparing a respective one of said choice words with each said relevance indicator to select one or more of said passages from said reference source.

comparing one of said context words with each said relevance indicator to select one or more of said passages from said reference source, and

generating a correlation signal for each of said respective choice words by correlating said passages of said context words with said passages of said respective choice words, to represent the likelihood that said choice word is a match for the ambiguous word.

25. A method according to claim 24 for use with a continuous speech recognition system, wherein

said step of generating said list of choice words, includes the steps of comparing select characteristics of a portion of speech to one or more word models each being representative of a word in a vocabulary, and

selecting as a function of said comparison a subset of said words from said vocabulary.

26. A method according to claim 24 wherein said step of providing a a reference source includes the step of

providing a reference source comprising a dictionary.

27. A method according to claim 24 wherein said step of providing a reference source includes the step of

providing a reference source comprising an encyclopedia.

28. A method according to claim 24 wherein the step of selecting passages from a reference source includes the steps of

comparing the choice word with each said relevance indicator, and selecting passages having a relevance indicator that contains a word that substantially matches the choice word, and

comparing a representative one of said context words with each said relevance indicator, and selecting passages associated with a relevance indicator that substantially matches the context word.

29. A method according to claim 24 wherein said step of selecting passages includes the steps of

selecting a choice word and a context word, each being in a first language,

translating said selected choice word and said context word into a second language,

accessing a reference source comprising information recorded in the second language and selecting said one or more passages therefrom, and

generating said correlation signal as a function of said selected passages recorded in the second language.

30. A method according to claim **24** wherein the step of generating said correlation signal includes the step of

determining for each choice word, a word count representative of the number of distinct words in the choice word passage that occur within a passage associated with one of the context words and generating said correlation signal as a function of said word count.

31. A method according to claim **30** wherein said step of generating said correlation signal includes the further step of

determining a frequency count for each passage word representative of the number of times the passage word occurs in a passage, and

generating said correlation signal as function of said word count weighted by said frequency count.

32. A method according to claim **24** wherein said step of generating a correlation signal includes the further steps of

generating an occurrence signal for each of said choice words as a function of an n-gram language model and one or more of said context words to represent the likelihood that said choice word would be selected from a set of vocabulary words, and

combining said occurrence signal with said correlation signal to adjust said correlation signal as a function of said likelihood of occurrence for said choice word.

33. A method according to claim **24** wherein said step of generating said correlation signal includes the step of

adjusting said correlation signal as a function of a word count signal representative of the number of words separating one of the context words from the ambiguous word being recognized.

34. A method according to claim **24** wherein the step of generating the correlation signal includes the step of comparing the selected passages associated with a context word and the selected passages associated with a choice word to detect a matching n-gram.

35. A method for ascertaining an ambiguous phrase that occurs in a data string which includes at least one context word, comprising the steps of

generating a list of one or more choice phrases, each of which represents one or more words, to represent choices for the ambiguous phrase,

providing a reference source having one or more passages, each passage including a relevance indicator and a series of words associated with the relevance indicator,

selecting as a function of one or said words in said choice phrase and each said relevance indicator, at least one of said passages from said reference source,

generating a correlation signal, as a function of said selected passage, and at least one of said context words, to represent the likelihood that said choice phrase is a match for the ambiguous phrase, and

selecting, as a function of said correlation signal, at least one of said choice phrases to represent the ambiguous phrase being identified.

36. A method according to claim **35** wherein the step of selecting passages includes the step of

selecting a passage for each of a plurality of the words in the choice phrase.

37. A method according to claim **35** wherein the step of generating a correlation signal includes the step of

generating for each choice phrase a word count signal representative of the number of words in the selected passages that match the words in the respective choice phrase.

38. A method according to claim **35** wherein the step of selecting passages from a reference source includes the step of

comparing at least one word of the choice phrase with the relevance indicators, and selecting passages having a relevance indicator that contains a word that substantially matches said word of the choice phrase.

39. Apparatus for recognizing an ambiguous word that occurs in a data string which includes at least one context word, comprising

means for providing a list of one or more choice words to represent choices for said ambiguous word,

means for selecting a choice word and for accessing a reference source having one or more passages, each passage including a relevance indicator and a series of words associated with the relevance indicator, to provide a list of passage words having a known association with said selected choice word,

means for generating a correlation signal for each of said choice words as a function of said passage words, to represent the likelihood that said choice word is substantially similar to said ambiguous word, and

means for selecting, as a function of said correlation signal, at least one of said choice words to represent said ambiguous word.

40. Apparatus according to claim **39** wherein said means for providing a list of passage words comprises

means for selecting one or more of said passage words from an electronically addressable reference source having information related to said selected choice word.

41. Apparatus according to claim **39** wherein said choice word is in a first language and said reference source contains passages in a second language, further including

translating means for translating said selected choice word into the second language to provide a list of passage words in the second language.

42. In an apparatus that employs context for recognizing an ambiguous word that occurs in a data string which includes one or more context words, the improvement comprising

means for selecting a list of one or more choice words to represent choices for said ambiguous word, means for accessing a reference source, having one or more each passage including a relevance indicator and a series of words associated with the relevance indicator, to provide a list of passage words having a known association with said selected word, and

means for selecting, as a function of each relevance indicator, at least one of said choice words to represent said ambiguous word.

43. Apparatus for recognizing an ambiguous word that occurs in a data string which includes at least one context word, comprising

means for providing a list of one or more choice words to represent choices for said ambiguous word,

means for selecting said context word and for accessing a reference source, having one or more passages, each passage including a relevance indicator and a series of words associated with the relevance indicator, to provide a list of passage words having a known association with said selected context word,

means for generating a correlation signal for each of said choice words as a function of said passage words, to represent the likelihood that said choice word is substantially similar to said ambiguous word, and

means for selecting, as a function of said correlation signal, at least one of said choice words to represent said ambiguous word.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,680,511

DATED : Oct. 21, 1997

INVENTOR(S) : Baker et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At column 30, line 40, please replace "more" with --more passages,--.

Signed and Sealed this

First Day of June, 1999

Attest:

Attesting Officer

Q. TODD DICKINSON

Acting Commissioner of Patents and Trademarks