

US00RE40458E

(19) **United States**
(12) **Reissued Patent**
Fredenburg

(10) **Patent Number:** **US RE40,458 E**
(45) **Date of Reissued Patent:** ***Aug. 12, 2008**

(54) **SYSTEM AND METHOD FOR USING A CORRESPONDENCE TABLE TO COMPRESS A PRONUNCIATION GUIDE**

5,680,601 A 10/1997 Rust
5,799,276 A 8/1998 Komissarchik et al. 704/251
5,815,639 A * 9/1998 Bennett et al. 704/235
5,930,756 A 7/1999 Mackie et al. 704/260
5,940,796 A * 8/1999 Matsumoto 704/260
6,047,298 A * 4/2000 Morishita 715/532

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(*) Notice: This patent is subject to a terminal disclaimer.

FOREIGN PATENT DOCUMENTS

JP 05067075 * 3/1993

(21) Appl. No.: **10/342,435**
(22) Filed: **Jan. 13, 2003**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **6,178,397**
Issued: **Jan. 23, 2001**
Appl. No.: **09/169,190**
Filed: **Oct. 8, 1998**

U.S. Applications:

(63) Continuation of application No. 08/665,404, filed on Jun. 18, 1996, now Pat. No. 5,845,238.

(51) **Int. Cl.**
G06F 17/20 (2006.01)
G06F 17/21 (2006.01)
G06F 17/22 (2006.01)

(52) **U.S. Cl.** **704/1; 704/10; 704/E15.02**

(58) **Field of Classification Search** None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,779,080 A 10/1988 Coughlin et al. 345/157
4,876,541 A 10/1989 Storer
5,189,610 A 2/1993 Kaplan et al.
5,325,091 A 6/1994 Kaplan et al.
5,333,313 A 7/1994 Heising 704/1
5,500,920 A 3/1996 Kupiec
5,523,946 A 6/1996 Kaplan et al.
5,530,645 A 6/1996 Chu 707/532
5,551,049 A 8/1996 Kaplan et al.
5,649,221 A 7/1997 Crawford et al. 707/532
5,673,362 A 9/1997 Matsumoto 704/260

OTHER PUBLICATIONS

van den bosh et al., Data-Oriented Methods for Grapheme-to-Phoneme Conversion, Proceedings of the Conference of the European Chapter of the ACL, 6, (1993), pp. 45-53.*
Bell et al., Modeling the Text Compression, ACM Computing Surveys, Vo. 21, No. 4, Dec. 1989.*
Furness, Spelling for the Millions, Thomas Nelson, Inc, NY, 1977, pp. 157-162.*
* cited by examiner

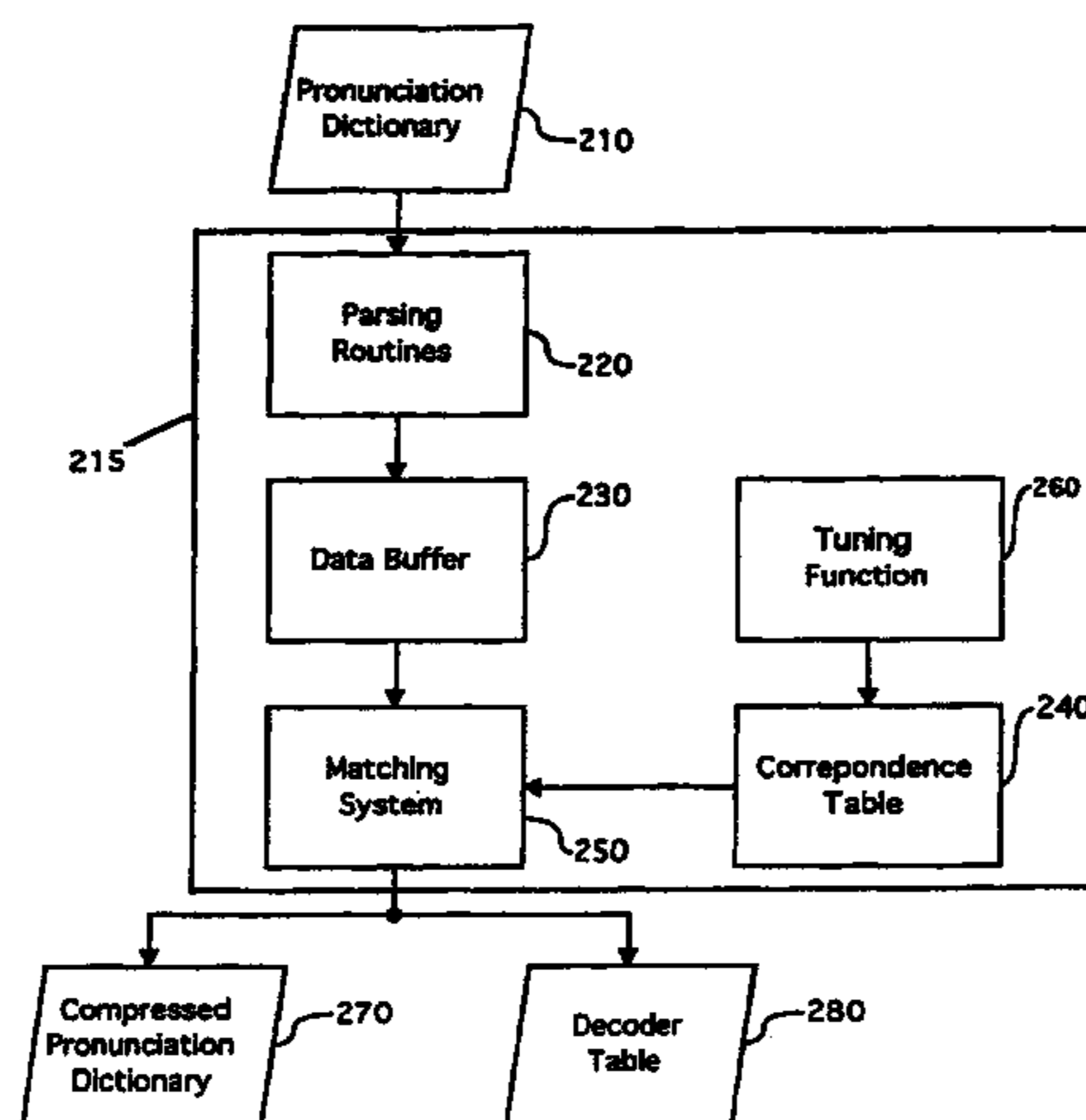
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(57) **ABSTRACT**

Parsing routines extract from a conventional pronunciation dictionary an entry, which includes a dictionary word and dictionary phonemes representing the pronunciation of the dictionary word. A correspondence table is used to compress the pronunciation dictionary. The correspondence table includes correspondence sets for a particular language, each set having a correspondence text entry, a correspondence phoneme entry representing the pronunciation of the correspondence text entry and a unique correspondence set identifying symbol. A matching system compares a dictionary entry with the correspondence sets, and replaces the dictionary entry with the symbols representing the best matches. In the absence of a match, symbols representing silent text or unmatched phonemes can be used. The correspondence symbols representing the best matches provide compressed pronunciation dictionary entries. The matching system also generates decoder code sets for subsequently translating the symbol sets. A decoder system uses the decoder code sets for translating symbol sets in the compressed pronunciation dictionary to generate phonemes corresponding to selected text.

25 Claims, 7 Drawing Sheets



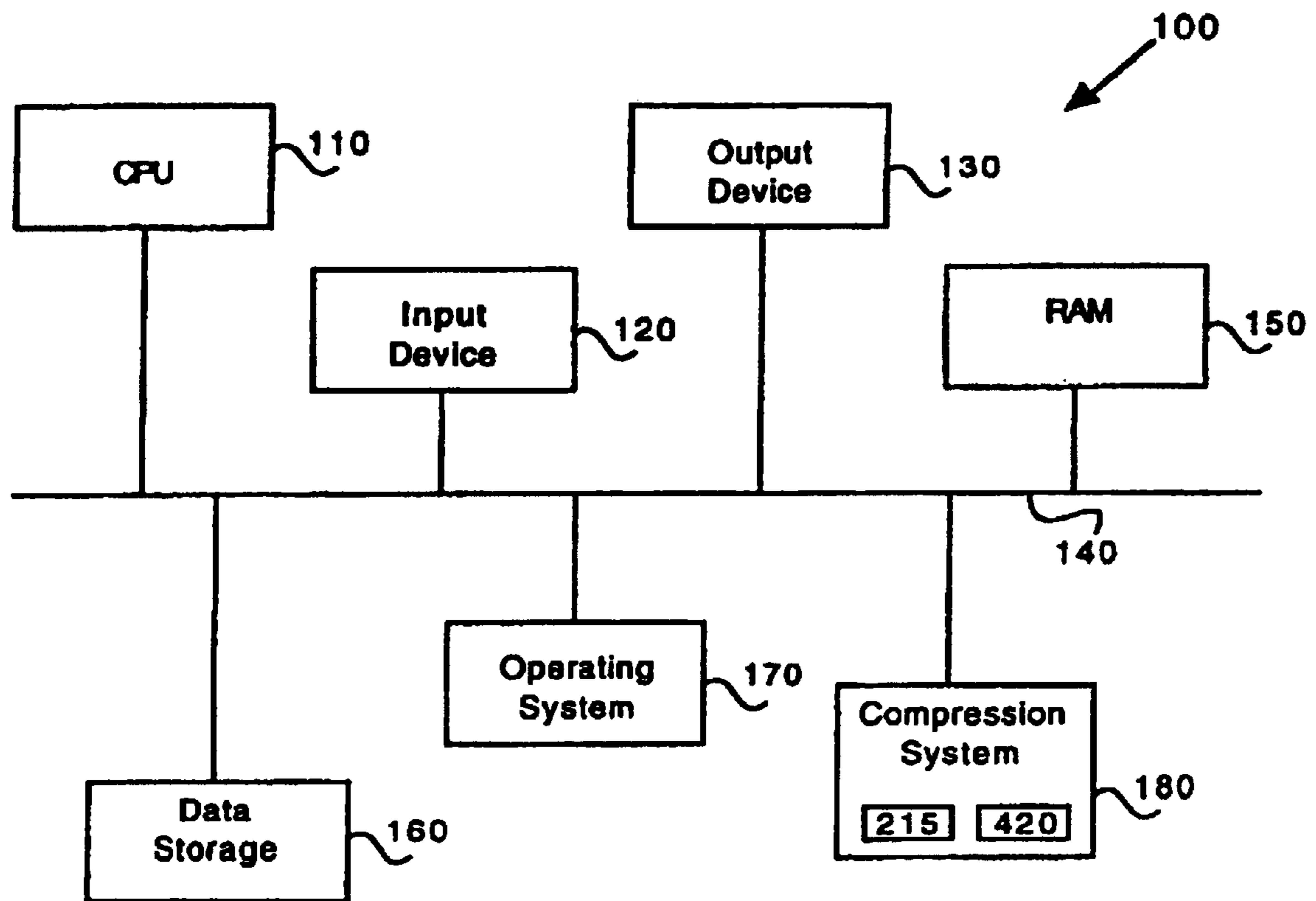


FIG. 1

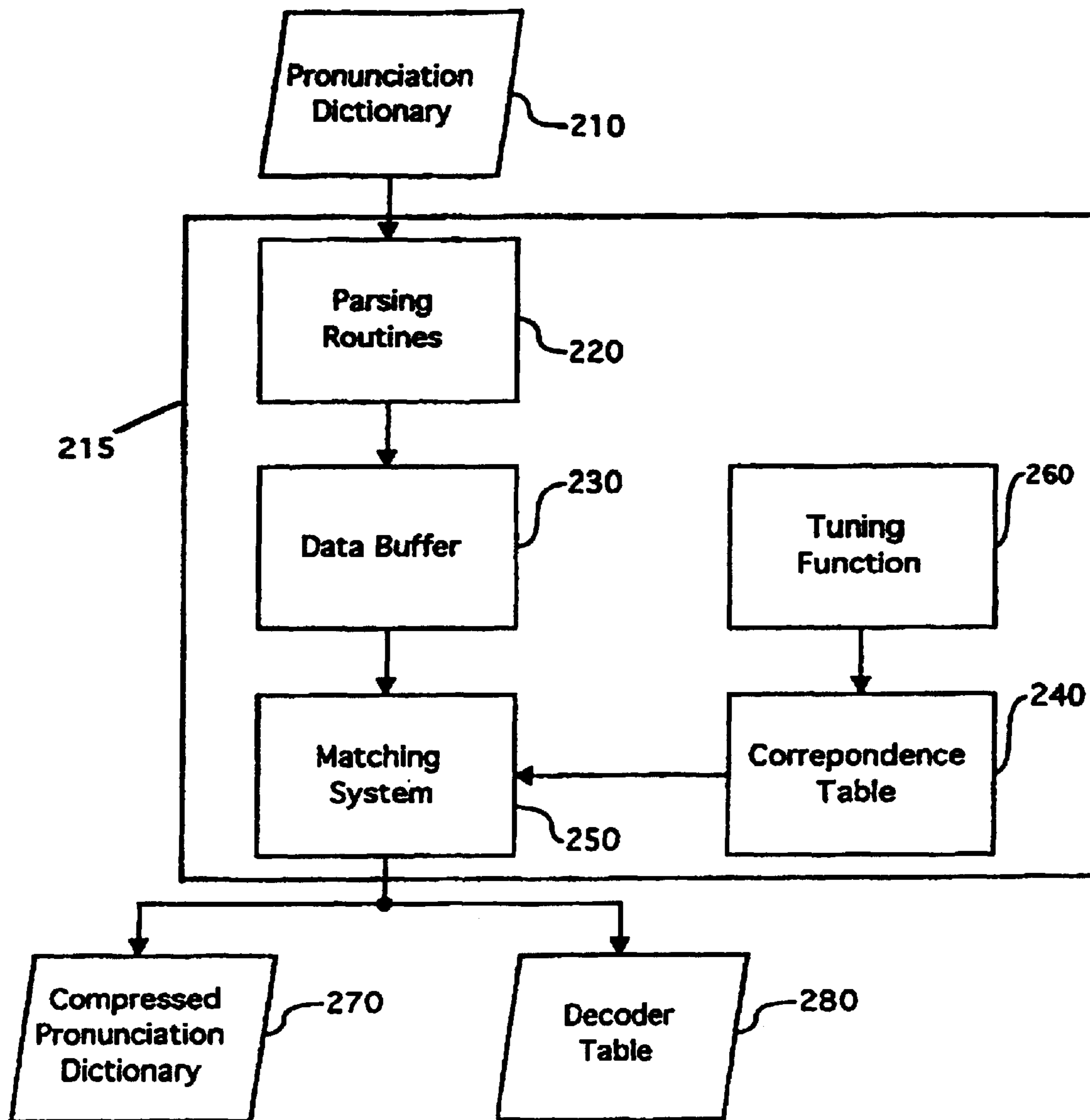


FIG. 2

FIG. 3: A Correspondence Table for American English

240

| Phoneme(s) | Text Entry | Symbol | Phoneme(s) | Text Entry | Symbol | Phoneme(s) | Text Entry | Symbol | Phoneme(s) | Text Entry | Symbol |
|------------------|------------|--------|-----------------|------------|--------|------------|------------|--------|------------|------------|--------|
| AE | ai | (7) | IX | e | (80) | d | d | | s | s | |
| AE | a | (8) | IX | ieu | | d | ed | | s | z | |
| EY | ai | (9) | IX | io | | d | tt | | S | c | |
| EY | ae | (10) | IX | ie | | d | t | | S | ch | |
| EY | ay | (11) | IX | i | | D | th | (120) | S | ss | |
| EY | a | | IX | ou | | f | ff | | S | s | |
| EY | ay | | IX | eu | | f | f | | S | l | |
| EY | e | | IX | y | | l | gh | | ts | z | (180) |
| AO | av | (13) | IX | . | | l | ph | | t | d | |
| AO | a | | AA | aa | (70) | gz | x | | t | ed | |
| AO | oa | | AA | a | | gZ | x | | t | th | |
| AO | ou | | AA | e | | g | gg | | t | tt | |
| AO | e | | AA | ow | | g | gh | | l | l | |
| AX _k | c | | AA | a | | g | g | | T | th | |
| AX _l | l | | AA | a | | h | h | (130) | v | r | |
| AX _m | m | | UW | ew | | h | j | | v | z | |
| AX | a | | UW | oo | | h | x | | w1AA | oi | |
| AX | ia | (20) | UW | eu | | J | dg | | w1UX | o | (180) |
| AX | i | | UW | e | | J | dj | | wAA | oi | |
| AX | o | | UW | u | | J | d | | wUX | o | |
| AX | u | | UW | u | | J | g | | w | u | |
| AX | y | | UW | u | | J | l | | w | w | |
| AX | . | | UH | ie | (80) | kw | cqu | | y1UH | u | |
| IY _{IX} | u | | UH | e | | ks | x | (140) | y1UW | u | |
| IY | oo | | UH | oo | | kS | x | | y1UW | ew | |
| IY | ee | | UH | u | | kT | th | | y1UX | u | |
| IY | ee | | LX _r | r | | k | cc | | yUH | u | |
| IY | oo | (30) | LX | a | | k | ch | | yUW | ew | (200) |
| IY | oy | | LX | eu | | k | ck | | yUW | ieu | |
| IY | a | | LX | e | | k | c | | yUW | u | |
| IY | ia | (30) | LX | ou | (80) | k | k | | yUX | u | |
| IY | i | | LX | ou | | k | ik | | yIX | u | |
| IY | l | | LX | u | | k | qu | | yAX | u | |
| IY | oo | | LX | y | | x | q | | yAX | u | |
| IY | y | | OW | au | (100) | l | ll | (150) | yAA | o | |
| EH | ae | | OW | a | | l | l | | y | l | |
| EH | al | | OW | ew | | l | xl | | y | ll | (210) |
| EH | a | | OW | ea | | m | fm | | y | y | |
| EH | oa | (40) | OW | ou | | m | mm | | z | es | |
| EH | e | | OW | ow | | m | m | | z | s | |
| EH | u | | OW | e | | ny | gn | | z | z | |
| H | a | | AW | ao | (100) | n | en | | z | z | |
| H | e | | AW | au | | n | gn | | Z | g | |
| H | i | | AW | a | | n | kn | (180) | Z | i | |
| H | o | | AW | ou | | n | nn | | Z | ss | |
| H | u | | AW | ow | | n | n | | Z | s | |
| H | y | | OY | aw | | N | ng | | Z | s | (220) |
| AY | ae | | OY | oi | | N | n | | Z | z | |
| AY | ai | (50) | OY | oy | | p | pp | | | | |
| AY | a | | P | bb | | p | p | | | | |
| AY | i | | P | b | | rr | r | | | | |
| AY | y | | C | ch | (110) | r | er | | | | |
| IX _l | ln | | C | c | | r | rr | | | | |
| IX _n | n' | | C | s | | r | r | | | | |
| IX | ee | | C | sch | | s | c | (170) | | | |
| IX | a | | C | l | | s | sc | | | | |
| IX | eeu | | d | dd | | s | ss | | | | |
| IX | ee | | | | | | | | | | |

FIG. 3

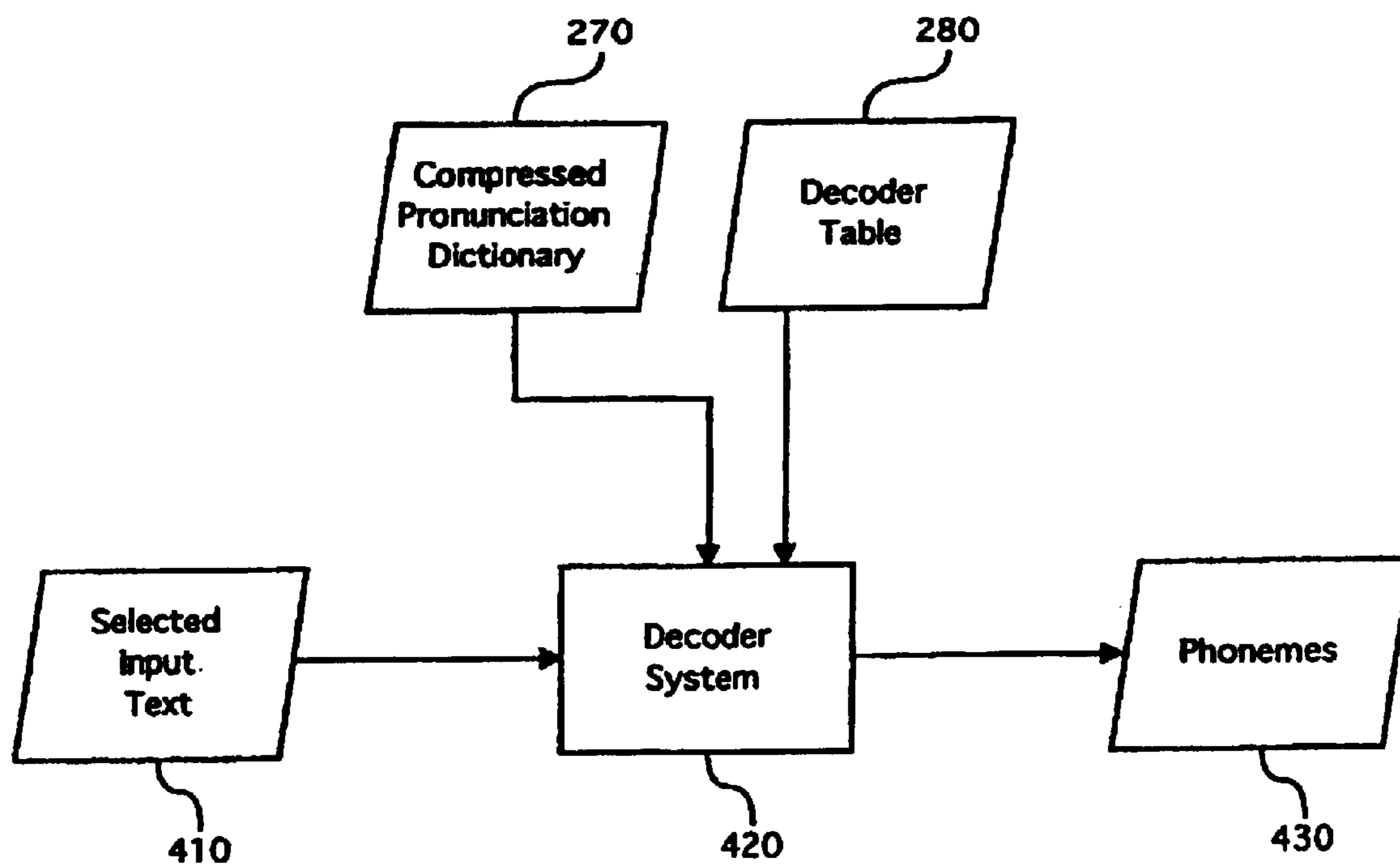


FIG. 4

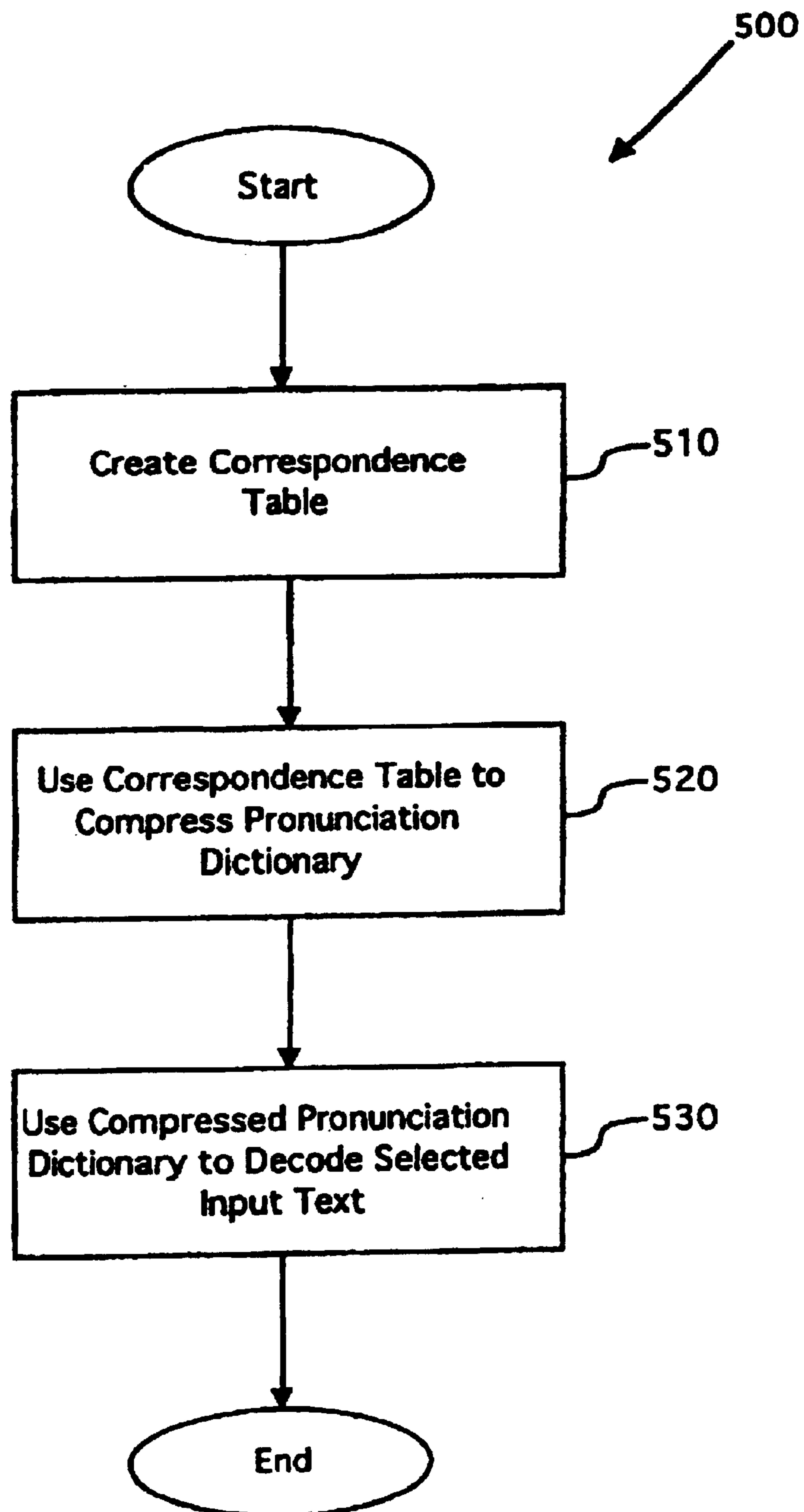
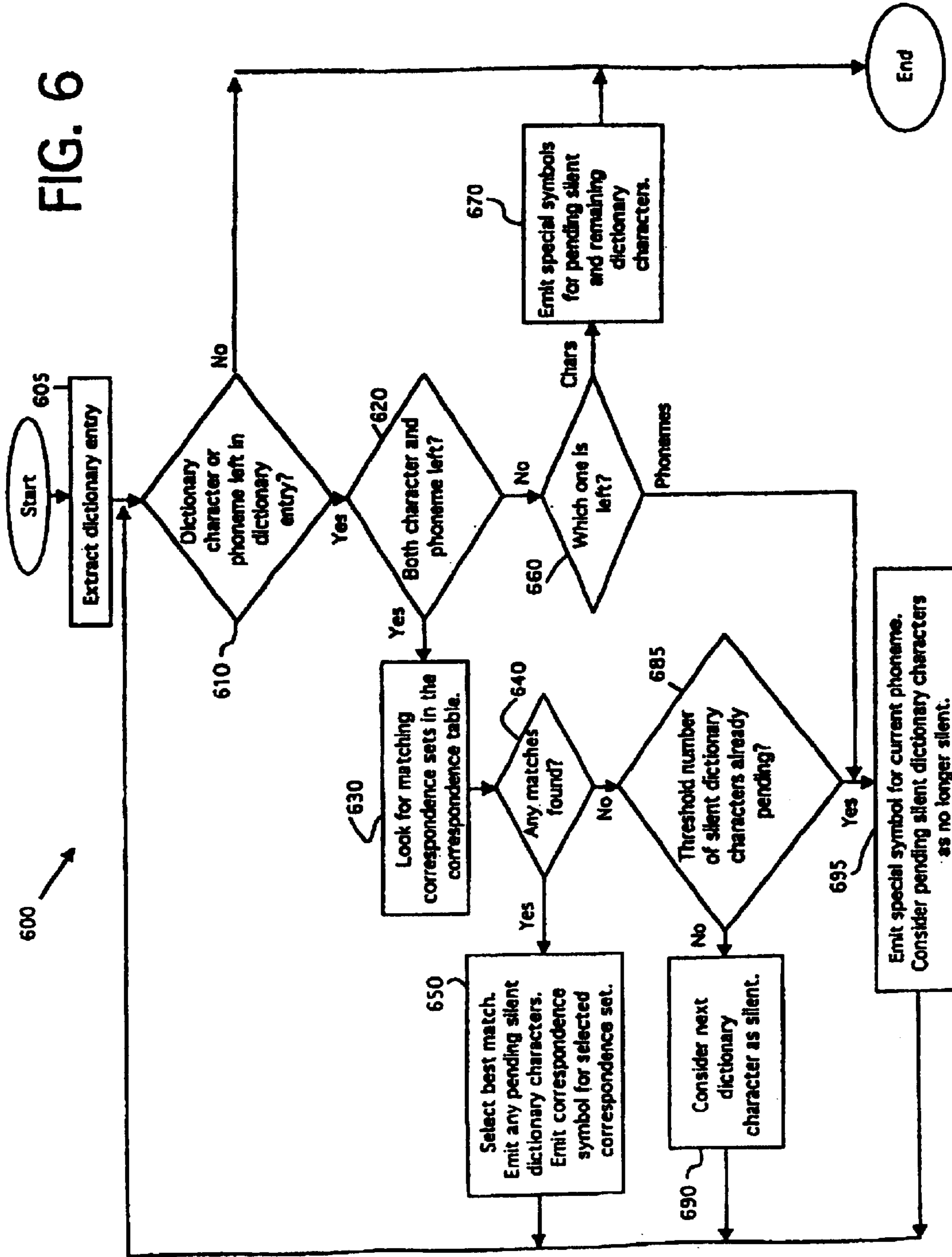


FIG. 5

FIG. 6



Phoneme Set for American English

700



| <u>Phoneme symbol</u> | <u>Example</u> |
|-----------------------|----------------|
| AE | bat |
| EY | bait |
| AO | caught |
| AX | about |
| IY | beet |
| EH | bet |
| IH | bit |
| AY | bite |
| IX | roses |
| AA | cot |
| UW | boot |
| UH | book |
| OW | boat |
| AW | bout |
| OY | boy |
| b | bin |
| C | chin |
| d | din |
| D | them |
| f | fin |
| g | gain |
| h | hat |
| J | jump |
| k | kin |
| l | limb |
| m | mat |
| n | nat |
| N | tang |
| p | pin |
| r | ran |
| s | sin |
| t | tin |
| T | thin |
| v | van |
| w | wet |
| y | yet |
| z | zen |
| Z | measure |

FIG. 7

**SYSTEM AND METHOD FOR USING A
CORRESPONDENCE TABLE TO COMPRESS
A PRONUNCIATION GUIDE**

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This is a continuation of application Ser. No. 08/665,404, filed on Jun. 18, 1996 now U.S. Pat. No. 5,845,238.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to data compression, and more particularly to a system and method using correspondence techniques to compress a pronunciation guide.

2. Description of the Background Art

Computer Random Access Memory (RAM) and disk space are becoming more available and affordable in desktop computer systems. A typical desktop computer system currently provides on the order of sixteen megabytes of RAM and one gigabyte of hard disk memory. This increasing availability allows programmers the freedom to create application programs and data files which occupy several megabytes of computer memory. However, minimizing the size of data files remains important for optimizing system performance and use of memory resources.

To minimize storage requirements, programmers compress large data files. One type of large file is a pronunciation dictionary, which includes dictionary words for a language such as American English and dictionary phonemes (phonetic sounds) representing the pronunciation of each of the dictionary words. A typical uncompressed pronunciation dictionary occupies up to about ten megabytes of memory.

Information such as a pronunciation dictionary can be compressed using certain symbols to replace redundant data. For example, a typical compression technique assigns symbols to represent particular patterns of redundant data such as multiple zeros or one. Multiple compression techniques may be performed successively to eliminate more redundancies and compress data further. Accordingly, a pronunciation dictionary may be compressed to around thirty percent or less of its original size.

Previous techniques for compressing pronunciation dictionaries do not take into account redundancies inherent in dictionary words and dictionary phonemes. Therefore, as an addition to other techniques for compressing a pronunciation dictionary, it is desirable to have a system and method for taking advantage of redundancies in pronunciation.

SUMMARY OF THE INVENTION

The present invention overcomes limitations and deficiencies of previous systems by providing a new system and method for compressing a pronunciation guide such as a pronunciation dictionary. The system substitutes a single symbol for some text and its pronunciation, and includes a central processing unit (CPU) and memory. The memory stores a compression system including parsing routines, a correspondence table, a matching system, a decoder table and a decoder system. The parsing routines extract a dictionary entry, which comprises a dictionary word and corresponding dictionary phonemes representing the pronunciation of the dictionary word, from an uncompressed pronunciation dictionary also stored in the memory. The correspondence table is made up of correspondence sets, each

of which has a text entry, a phoneme entry representing the pronunciation of the text entry, and a set-identifying symbol (i.e., a number). The matching system attempts to find all correspondence sets that match text and phoneme combinations of the dictionary entry.

If matches are found, then the matching engine selects the best matches and adds the representative correspondence symbol set to a compressed pronunciation dictionary. If a match is not found, then the matching system considers characters silent and/or phonemes unmatched, and assigns special symbols to be added to the compressed pronunciation dictionary. The matching system adds decoder code sets to a decoder table for translating the special symbols back to characters or phonemes.

The decoder system uses the compressed pronunciation dictionary and decoder code sets to generate corresponding phonemes for selected text. These phonemes can be used in processes such as speech recognition, speech synthesis, language translation, foreign language learning, spell checking, etc.

The present invention provides a method for compressing a pronunciation dictionary. The method creates a correspondence table comprised of correspondence sets, determines which correspondence sets match a dictionary word and its corresponding dictionary phonemes, and adds the correspondence symbols as compressed data entries to a compressed pronunciation dictionary. The invention also provides a method for using the compressed dictionary and decoder code sets to generate phonemes from input text.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a computer system including a compression system in accordance with the present invention;

FIG. 2 is a block diagram showing dictionary compressing components of the FIG. 1 compression system used to construct a compressed pronunciation dictionary;

FIG. 3 is a text-phoneme correspondence table for American English;

FIG. 4 is a block diagram showing components of the FIG. 1 compression system used in application of the compressed dictionary;

FIG. 5 is a flowchart illustrating the preferred method for compressing a pronunciation dictionary and using the compressed pronunciation dictionary for decoding selected text;

FIG. 6 is a flowchart further illustrating steps of the preferred method for compressing an entry from a pronunciation dictionary; and

FIG. 7 is an example phoneme set for American English.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENT

FIG. 1 is a block diagram of a computer system **100** including a compression system **180** in accordance with the present invention. Computer system **100** is preferably based on a computer such as a Power Macintosh manufactured by Apple Computer, Inc. of Cupertino, Calif. Computer system **100** includes a Central Processing Unit (CPU) **110**, an input device **120** such as a keyboard and mouse or scanner, and an output device **130** such as a Cathode Ray Tube (CRT) or audio speaker, a Random Access Memory (RAM) **150**, a data storage (hard disk) **160**, an operating system **170** and a compression system **180**, each coupled to signal bus **140**.

Operating system **170** is a program that controls processing by CPU **110**, and is typically stored in data storage **160**

and loaded into RAM 150 during computer system initialization. CPU 110 has access to RAM 150 for storing intermediate results and miscellaneous data.

Compression system 180 includes a dictionary compressing program 215 for compressing a pronunciation dictionary, and a decoder system program 420 for subsequently processing text and using the compressed pronunciation dictionary to retrieve phonemes representing the pronunciation of the text. Compression system 180 is also typically stored in data storage 160 and loaded into RAM 150 prior to execution by CPU 110.

FIG. 2 is a block diagram illustrating dictionary compressing program 215 of compression system 180, used with a pronunciation dictionary 210 to construct a compressed pronunciation dictionary 270. Pronunciation dictionary 210 is preferably a conventional compilation of dictionary words and of corresponding dictionary phonemes in a specified format expressing proper pronunciation of the dictionary words in, for example, American English. Suitable pronunciation dictionaries include the Oxford-American® Dictionary. FIG. 7 illustrates an example phoneme list 700 for American English. List 700 includes thirty-eight phonemes and an example word which uses each phoneme. For example, the phoneme "AE" provides the sound made by the letter "a" as in the word "bat." Other phonemes or sound-representative symbols can alternatively be used.

Dictionary compressing program 215 includes parsing routines 220, a data buffer 230, a correspondence table 240, a matching system 250 and a tuning function 260. Parsing routines 220 extract a dictionary entry, which includes a dictionary word and at least one dictionary phoneme representing the pronunciation of the word, from pronunciation dictionary 210. For the example word "enough", the extracted dictionary entry includes the dictionary word "enough" and the corresponding phonemes "IH n UX f". Parsing routines 220 store the extracted dictionary entry in data buffer 230, which may be a portion of RAM 150 (FIG. 1).

Correspondence table 240 lists phoneme entries and text entries, for example, as shown for American English in FIG. 3. A text entry, a phoneme entry and a symbol together form a correspondence set, and a plurality of correspondence sets forms correspondence table 240. Each correspondence set includes an identifier, referred to as a correspondence symbol, which may be simply the address of the set in correspondence table 240.

Correspondence table 240 preferably includes correspondence sets for most practical combinations of correspondence text and phonemes in a given language. A correspondence table 240 which included every conceivable correspondence set would be inefficient because increasing the number of code sets degrades compression by subsequent compression techniques. Therefore, a tuning function 260 facilitates eliminating the less useful correspondence sets from, and adding more useful correspondence sets to, correspondence table 240. The utility or productivity of a correspondence set is determined by the number of dictionary entries it helps to compress. A pronunciation dictionary may be compressed a first time, and the compressed dictionary examined to determine if any correspondence sets are used less than, say, five times. If so, the less used and thus unproductive correspondence sets can be eliminated or modified. Further, since phonemes typically have corresponding text, cases where a phoneme does not match any text may indicate a need to add a correspondence set.

Matching system 250 is a program which reads the extracted dictionary entry from buffer 230, retrieves corre-

spondence sets from correspondence table 240, and compares the dictionary entry with the correspondence sets. More particularly, matching system 250 attempts to match the correspondence sets with combinations of phonemes and characters from the dictionary entry. If matches are made, matching system 250 assigns the correspondence symbol associated with the "best" matching correspondence set as a compressed data entry, as described below with reference to FIG. 6. If a match cannot be made for a particular dictionary character or phoneme, matching system 250 assigns, as compressed data entries, special symbols to represent silent characters or unmatched phonemes. The one or more compressed data entries representing an entire dictionary entry forms a "symbol set." The symbol sets for an entire pronunciation dictionary collectively form the "compressed pronunciation dictionary" 270.

Matching system 250 further generates decoder code sets for de-compressing compressed pronunciation dictionary 270, and adds the code sets to a "decoder table" 280. Each decoder code set includes a decoder text entry, a corresponding decoder phoneme entry, and a decoder set-identifying symbol equivalent to a correspondence symbol of correspondence table 240. Decoder table 280 is like correspondence table 240 except that decoder table 280 also includes decoder sets for the silent text characters and the unmatched phonemes. The decoder sets are described in more detail with reference to FIGS. 4 and 5.

FIG. 3 shows an example correspondence table 240 for American English. The first column specifies correspondence phoneme entries, the second column specifies correspondence text entries, and the third column specifies correspondence symbols. A correspondence text entry specifies text characters such as "e" or "ou," and is accompanied by typically only one phonetic sound. A correspondence phoneme entry, such as "IH," is expressed in the format used by pronunciation dictionary 210, for representing the phonetic sound of each correspondence text entry. Since some text entries produce multiple sounds, a phoneme entry may represent multiple sounds such as "y UH." Further, there may be correspondence entries which have multiple text characters and multiple phonemes, like "y UW→ieu."

The correspondence sets may be organized into groups of rows of like phonemes. Grouping rows based on phonemes facilitates comparisons with dictionary combinations if creating table 240 by hand. In the first row of table 240, correspondence phoneme "AE" represents one of the possible pronunciations of correspondence text entry "ai", and this correspondence set is represented by the symbol "(1)". In the second row, the same correspondence phoneme "AE" represents one of the possible pronunciations of a different correspondence text entry, "a", and this correspondence set is represented by the symbol "(2)". In the third row, correspondence phoneme "EY" represents another pronunciation of the same correspondence text entry "ai" in the first row, and this correspondence set is represented by symbol "(3)". These three rows illustrated how the same text entry may have different pronunciations, and different text entries may have the same pronunciation.

Correspondence table 240 may be generated manually, i.e. by typing the table into a computer file, or generated electronically, i.e. by computer analysis of productive phoneme-text combinations. It will be appreciated that each language, such as American English or French, would use a different correspondence table 240.

FIG. 4 is a block diagram illustrating the decoder system program 420 of compression system 180, and its input and

output data. Selected input text **410** may be stored in data storage **160** and loaded into RAM **150** for examination. Decoder system program **420** receives a word from selected input text **410**.

Decoder system **420** uses the decoder table **280** codes to translate symbol sets of compressed pronunciation dictionary **270** in searching for the compressed dictionary word whose text matches the received word, and then in producing phonemes for the received word. If the dictionary compressing method compressed pronunciation dictionary **210** entries in the original alphabetical order of the dictionary words, then the symbol sets are entered in the same alphabetical order in compressed pronunciation dictionary **270**. Thus, decoder system **420** could approximate the location of the dictionary word which matches the input text word. Another embodiment of the dictionary compressing method provides an index to compressed pronunciation dictionary **270**. Further, any technique for searching a compressed file, such as a hashing function, may be used.

Upon matching a compressed dictionary word to the input text word, decoder system **420** uses the decoder table **280** codes to retrieve dictionary phonemes **430** from the matching symbol set. Alternatively, as it searches the compressed dictionary and converts symbol sets to find a dictionary word which matches the received text, decoder system **420** may also convert the symbol sets to produce phonemes at the same time.

For example, decoder system **420** receives the word "enough" from selected text **410**. Decoder system **420** uses decoder table **280** to decode symbol sets from compressed pronunciation dictionary **270** until decoding a symbol set to match the dictionary word "enough". Upon finding a match, decoder system **420** uses decoder table **280** to translate the symbol set into the output data phonemes "IH n UX f" representing the pronunciation of the received text.

FIG. **5** is a flowchart illustrating a method **500** for compressing pronunciation dictionary **210** and for using the compressed dictionary to generate representative phonemes from selected input text **410**. Method **500** begins in step **510** by creating a correspondence table **240** for a given language. Creating correspondence table **240** comprises the step of inputting a number of correspondence sets, each of which includes a phoneme entry expressing at least one phonetic sound and a text entry which indicates the phonetic sound or sounds, and inputting a correspondence set identifying symbol. Step **510** preferably includes inputting a correspondence set for each of the various text representations of all of the phonemes used in pronunciation dictionary **210**.

The step **510** preferably further includes tuning function **260** (FIG. **2**) using the current version of correspondence table **240** to compress at least a portion of pronunciation dictionary **210** for determining which correspondence sets are unproductive and what other correspondence sets may be valuable if added. Tuning function **260** may be re-applied to optimize correspondence table **240**, thereby enabling matching system **250** to more effectively compress pronunciation dictionary **210** and enabling compressed pronunciation dictionary **270** to be further compressed by subsequent compression techniques.

Program **215** in step **520** uses the optimized correspondence table **240** to compress pronunciation dictionary **210**. More particularly, parsing routines **220** extract a dictionary entry including a dictionary word and corresponding dictionary phonemes from pronunciation dictionary **210**, and store the dictionary entry in data buffer **230**.

Matching system **250** selects a first phoneme from the dictionary entry, and retrieves all correspondence sets from correspondence table **240** which start with the selected dictionary phoneme to determine if a match can be made. Mul-

iple dictionary characters which together constitute a correspondence text entry in correspondence table **240** are "related." Divisions between related dictionary characters are typically harder to determine than divisions between dictionary phonemes. Also, there are fewer dictionary phonemes without corresponding dictionary characters (e.g., as in abbreviations such as "Mrs." or "etc.") than there are "silent" dictionary characters without phonemes. Therefore, matching system **250** preferably selects a dictionary phoneme, and attempts to match correspondence sets based on the dictionary phoneme.

Matching system **250** compares the correspondence sets retrieved from correspondence table **240** with the dictionary entry to determine if any matches can be made. If only one match is made, matching system **250** selects the correspondence symbol associated with the matching correspondence set as the compressed data entry for compressed pronunciation dictionary **270**. If more than one match can be made, matching system **250** selects as the compressed data entry for compressed pronunciation dictionary **270** the symbol for the correspondence set corresponding to the best match. If no match can be made, matching system **250** generates special symbols to represent "silent" characters, or conversely generates special symbols to represent phonemes unmatched to dictionary text. Generation of special symbols is described in greater detail with reference to FIG. **6**. If a special symbols is generated, a decoder code set representing the association of the special symbol to the silent character or alternatively to the unmatched phoneme is added to decoder table **280** for subsequently decoding the special symbol.

Matching system **250** then selects the next unprocessed phoneme, and repeats step **520** until the compressed data entries have been generated for the entire dictionary entry. Examples of this process are described with reference to Examples 1-3. After all the pronunciation dictionary **210** entries have been compressed, the symbol set, which possibly includes special symbols, is added to compressed pronunciation dictionary **270**. It will be appreciated that step **510** and step **520** are typically performed by a product developer.

Decoder system **420** in step **530** uses compressed pronunciation dictionary **270** and decoder table **280** to generate phonemes for selected text **410**. Decoder system **420** receives a selected word from text **410**, and then uses decoder table **280** to decode symbol sets from compressed pronunciation dictionary **270** until one of the decoded dictionary words matches the first input word. Decoder system **420** next uses decoder table **280** to retrieve the dictionary phonemes from the matching symbol set, and then method **500** ends for the first input word. Step **530** repeats for subsequently received words. It will be appreciated that step **530** is typically performed by a customer.

FIG. **6** is a flowchart illustrating a preferred method **600** for compressing an entry from pronunciation dictionary **210**. Method **600** is repeated for every word in the dictionary to accomplish FIG. **5** step **520**. Method **600** begins in step **605** by matching system **250** reading a dictionary entry, which comprises a dictionary word and a dictionary phoneme entry representing the pronunciation of the dictionary word, from buffer **230**. Matching system **250** in step **610** determines whether any dictionary characters or dictionary phonemes remain unprocessed in the dictionary entry. If not, method **600** ends. Otherwise, matching system **250** in step **620** determines whether both a dictionary character and a dictionary phoneme remain.

If both remain, matching system **250** in step **630** searches correspondence table **240** for all correspondence sets that match dictionary phoneme-character combinations of the remaining portions of the dictionary entry. More

Lastly, matching stem **250** selects the dictionary phoneme “r” and retrieves the correspondence sets (r→rr, r→er, rr→r, r→r).

AE n s UX r

answe r

Matching system **250** finds only one match (r→r), and selects the symbol “(155).” Matching system **250** adds “2 161 173 221 87 155” to compressed pronunciation dictionary **270** as a symbol set representing the word “answer” and the phonemes “AE n s UX r.”

EXAMPLE 3

“r IH D AX m” and “rhythm”

Matching, system **250** retrieves the dictionary word “rhythm” and the dictionary phonemes “r IH D AX m,” selects the first dictionary phoneme “r” and retrieves the correspondence sets (r→rr, r→er, rr→r, r→r).

r IH D AX m

rhythm

Matching system **250** finds only one match (r→r), and remembers the symbol “169.”

Matching system **250** selects the next unprocessed phoneme “IH” and retrieves the correspondence sets (IH→a, IH→e, IH→i, IH→o, IH→u, IH→y).

r IH D AX m

rhythm

Matching system **250** finds no matches. Accordingly, matching system **250** assumes the “h” is silent. With the “h” silent, matching system **250** then examines the remaining portions of the dictionary entry.

r IH D AX m

rh ythm

Matching system **250** finds a match (IH→y), assigns a special symbol such as “222” for silent “h” and remembers the symbol “47.”

Matching system **250** then selects the next unprocessed phoneme “D” and retrieves only correspondence set (D→th), since in this example matching system **250** is case sensitive.

r IH D AX m

rhythm

Matching system **250** finds a match and remembers the symbol “120.”

Matching system **250** then selects the next unprocessed phoneme “AX” and retrieves the correspondence sets (AXk→c, AXl→l, AXm→m, AX→a, AX→e, AX→ia, AX→i, AX→o, AX→u, AX→y, AXE→’).

r IH D AX m

rhythm

Matching system **250** finds only one match (AXm→m), and remembers symbol “(16).” Since no other characters exist, matching system **250** adds “169 222 47 120 16” to compressed pronunciation dictionary **270** as a symbol set representing the dictionary word “rhythm” and the corresponding phonemes “r IH D AX m.”

If for example the correspondence set AXm→m was not included in correspondence table **240**, matching system **250** would find no match. Accordingly, matching system **250** would assume the text character “m” is silent. Since only characters would remain, matching system **250** would emit a special symbol such as “223” for current phoneme “AX” and would consider the text character “m” is no longer silent. Matching system **250** would then retrieve the correspondence sets (m→lm, m→mm, m→m) for phoneme “m”,

would find the only match m→m, and would remember the symbol “155.” Since no other characters would exist, matching system **250** would add “169 222 47 120 223 155” to compressed pronunciation dictionary **270** as a symbol set representing the dictionary word “rhythm” and the corresponding phonemes “r IH D AX m.”

The present invention advantageously provides a system and method for compressing a pronunciation dictionary. This is especially useful, for example, as a precursor to other compression techniques. The system and method take advantage of the natural redundancy between dictionary text and dictionary phonemes. Since compression system **180** substitutes symbols for sets of dictionary words and phonemes, memory required to store the information is reduced by approximately one-third to one-half.

For example, each character in a word may be represented by five bits (since there are twenty-six letters in the English alphabet), and each phoneme may be represented by six bits (since there are about thirty-nine phonemes for American English as illustrated in FIG. 7). Further, dictionary words and the set of phonemes for each dictionary word are divided by a terminator character. The word “enough” requires seven characters (including the terminator character) and thus occupies thirty-five bits. The corresponding phoneme set “IH n UX f” requires five characters (including the terminator character), and thus occupies thirty bits. Thus, the total memory for storing this dictionary entry is sixty-five bits.

A decoder table **280**, as shown in FIG. 3, has about **220** correspondence sets and **220** correspondence symbols. Accordingly, eight bits are needed to represent a correspondence symbol. As illustrated in the first example, the four symbols “(43)”, “(161)”, “(89)” and “(123)” represent the word “enough” and phonemes “IH n UX f”. Thus, five symbols (including the terminator character) are needed and occupy forty bits. Forty bits provides a thirty-eight percent savings over the uncompressed sixty-five bits.

The foregoing description of the preferred embodiments of the invention is by way of example only, and other variations are provided by the present invention. For example, components of this invention may be implemented using a programmed general purpose digital computer, using application specific integrated circuits, or using a network of interconnected conventional components and circuits. Further, although the invention has been described with reference to a dictionary, any guide having text and phonemes can be compressed using the system and method of the present invention. Still further, although the invention has been described using phonemes, other alternative means for representing pronunciation of text are possible, such as allophones, syllables or symbols generated by an earlier compression system. The embodiments described herein are presented for purposes of illustration and are not intended to be exhaustive or limiting. Many variations and modifications are possible in light of the foregoing teaching. The system is limited only by the following claims.

What is claimed is:

1. A computer [data storage medium storing a correspondence table which enables compression of] *program product for compressing* a pronunciation dictionary, the *computer program product comprising a computer-readable medium containing computer program code for:*

- generating a correspondence table comprising:*
 - a plurality of correspondence sets each including
 - a correspondence text entry that is part of a dictionary word;
 - a correspondence phoneme entry representing the pronunciation of the correspondence text entry; and

11

a correspondence symbol for identifying the correspondence set,

wherein at least one said correspondence symbol forms a symbol set for use as a compressed data entry in generating said compressed pronunciation dictionary.

2. The computer [data storage medium] *program product* of claim 1 further *comprising computer program code for:* storing a tuning function for optimizing said correspondence table.

3. The computer [data storage medium] *program product* of claim 2 wherein said tuning function eliminates redundant correspondence sets and low usage correspondence sets from said correspondence table.

4. The computer [data storage medium] *program product* of claim 1 wherein said correspondence table includes said correspondence sets for all practical combinations of said correspondence text entries and said correspondence phoneme entries for a given language.

5. The computer [data storage medium] *program product* of claim 1 further *comprising computer program code for:* storing[*:*] a grouping of a plurality of said correspondence sets.

[6. The computer data storage medium of claim 5 wherein correspondence phoneme entries of said grouping are similar to one another in pronunciation.]

7. The computer [data storage medium] *program product* of claim 1 wherein a matching system uses said correspondence phoneme entry to match said correspondence sets in generating said compressed pronunciation dictionary.

8. A system for storing a pronunciation guide comprising:
a memory element storing:

a correspondence table for storing pronunciation data; and
a tuning function for optimizing said correspondence table;

wherein said correspondence table includes at least one correspondence set having

a correspondence text entry that is part of a dictionary word,
a correspondence phonetic entry representing the pronunciation of said correspondence text entry, and
a correspondence symbol for identifying the correspondence set; and

wherein a matching system uses said correspondence phonetic entry to match said at least one correspondence set in generating a compressed pronunciation dictionary.

9. The system of claim 8 wherein said tuning function eliminates redundant correspondence sets from said correspondence table.

10. The system of claim 9 wherein at least one said correspondence symbol forms a symbol set for use as a compressed entry in generating said compressed pronunciation dictionary.

11. The system of claim 9 wherein said correspondence table includes a respective correspondence set for each practical combination of any correspondence text entry and any correspondence phonetic entry for a given language.

12. The system of claim 9 further comprising:
a grouping of a plurality of said at least one correspondence set.

[13. The system of claim 12 wherein said phonetic entries of said grouping are similar to one another in pronunciation.]

14. The system of claim 8 wherein said tuning function eliminates low usage correspondence sets from said correspondence table.

12

15. The system of claim 8 wherein said phonetic entry is a phoneme, an allophone, or a syllable.

16. A method of [storing] *generating* a pronunciation guide, comprising the steps of:

inputting a correspondence set into a correspondence table, *the correspondence set comprising a text entry and a phoneme entry representing the pronunciation of the text entry;* and

inputting into said correspondence table a correspondence symbol [corresponding to] *identifying* said correspondence set;

[wherein at least one said correspondence symbol forms a symbol set for use as a compressed entry in generating a compressed pronunciation dictionary] *and*

generating a pronunciation guide, wherein said correspondence symbol comprises an entry in the pronunciation guide.

17. The method of claim 16 further comprising the steps of:

optimizing said correspondence table; and

grouping said correspondence set into a plurality of said correspondence sets.

18. The method of claim 17 wherein said step of optimizing comprises the steps of:

eliminating redundant correspondence sets from said correspondence table;

eliminating low-usage correspondence sets from said correspondence table; and

adding productive correspondence sets to said correspondence table.

[19. The method of claim 16 wherein said step of inputting a correspondence set further comprises the steps of:

inputting a correspondence text entry that is part of a dictionary word into said correspondence table; and

inputting a phonetic entry corresponding to said correspondence text entry into said correspondence table.]

20. The method of claim [19] 16 further comprising the step of using said phonetic *phoneme* entry to generate said compressed pronunciation [dictionary] *guide.*

21. A computer program product for generating a compressed pronunciation dictionary, the computer program product comprising a computer-readable medium containing computer program code for:

generating a plurality of correspondence sets each including

a correspondence text that is part of a dictionary word;

a correspondence phoneme representing the pronunciation of the correspondence text; and

a correspondence symbol for identifying the correspondence set;

storing wherein the correspondence symbol in the compressed pronunciation dictionary.

22. A system for storing a pronunciation guide comprising:

a memory element storing:

a correspondence table for storing pronunciation data;
and

a tuning function for optimizing the correspondence data structure;

wherein the correspondence table includes at least one correspondence set having

a correspondence text that is part of a dictionary word,

a correspondence phoneme representing the pronunciation of the correspondence text, and

a correspondence symbol for identifying the correspondence set; and

13

wherein a matching system uses the correspondence phoneme to match the correspondence set in generating a compressed pronunciation dictionary.

23. A method of generating a pronunciation guide, comprising the steps of:

inputting a correspondence set into a correspondence table, the correspondence set comprising a text entry and a phoneme entry representing the pronunciation of the text entry; and

inputting into the correspondence table a correspondence symbol identifying the correspondence set; and generating a pronunciation guide, wherein the correspondence symbol comprises an entry in the pronunciation guide.

24. A computer-readable medium having instructions contained thereon, which, when executed by a processor, cause the processor to perform the operations of:

inputting a correspondence set into a correspondence table

inputting into the correspondence table a correspondence symbol identifying the correspondence set; and

generating a compressed pronunciation dictionary, wherein the correspondence symbol is used as an entry in the compressed pronunciation dictionary.

25. A system for compressing a pronunciation dictionary guide which includes a plurality of dictionary entries, each entry having a guide word and at least one associated phoneme representing the pronunciation of the word, the system comprising:

a computer-readable medium storing

(1) correspondence data which includes a plurality of correspondence sets, each set having

(i) a text entry,

(ii) a phoneme entry representing a pronunciation of the text entry, and

(iii) a symbol identifying the correspondence set; and

(2) a matching process for comparing a selected dictionary entry and the associated phonemes with the correspondence sets, and storing correspondence symbols which represent matching correspondence sets as a compressed pronunciation guide entry in the computer-readable medium; and

a processor coupled to the computer-readable medium for controlling the operations of the matching system.

26. A system for using a compressed pronunciation dictionary and decoder data to decode selected text, comprising:

memory storing

decoder data having a plurality of decoder code sets for translating symbol sets, each decoder code set includ-

14

ing a decoder text entry, a decoder phoneme entry and a decoder symbol representing the decoder code set;

a decoder process for using the decoder data to translate symbol sets to find a dictionary entry which matches the selected text, and upon finding a match using the decoder data

to retrieve the decoder phonemes from the matching symbol set; and

a processor coupled to the memory for controlling the operations of the decoder system.

27. A computer-based method for compressing a pronunciation guide which includes a plurality of dictionary entries, each entry having a dictionary text entry and at least one associated dictionary phoneme representing the pronunciation of the guide word dictionary text entry, comprising the steps of:

storing in a first portion of a computer memory correspondence data which includes a plurality of correspondence sets, each correspondence set including a correspondence text entry, a correspondence phoneme entry representing a pronunciation of the correspondence text entry and a unique correspondence symbol identifying the correspondence set;

receiving a dictionary text entry and at least one dictionary phoneme representing the pronunciation of the guide word;

comparing the dictionary text entry and dictionary phonemes with correspondence sets; and

storing the correspondence symbols representing matching correspondence sets as compressed pronunciation guide entries in a second portion of the computer memory.

28. A computer storage medium storing a computer program for causing a computer to perform the steps of:

storing decoder data which includes a plurality of decoder sets, each decoder set having a decoder text entry, a decoder phoneme entry representing the pronunciation of the decoder text entry, and a unique decoder set identifying symbol;

receiving selected text;

using the decoder data to decode a symbol set to produce a dictionary entry;

comparing the selected text with the dictionary entry to determine if they match; and

if a match is made, using the decoder data to retrieve the phoneme entries corresponding to a matching symbol set.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : RE 40,458 E
APPLICATION NO. : 10/342435
DATED : August 12, 2008
INVENTOR(S) : Timothy Fredenburg

Page 1 of 1

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

Column 11, line 53, after "set for," delete "us" and insert --use--.

Signed and Sealed this

Twenty-third Day of December, 2008

A handwritten signature in black ink that reads "Jon W. Dudas". The signature is written in a cursive style with a large, stylized initial "J".

JON W. DUDAS
Director of the United States Patent and Trademark Office