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(54) SYSTEM AND INTERACTIVE FORM FILLING WITH FUSION OF DATA FROM MULTIPLE UNRELIABLE INFORMATION SOURCES

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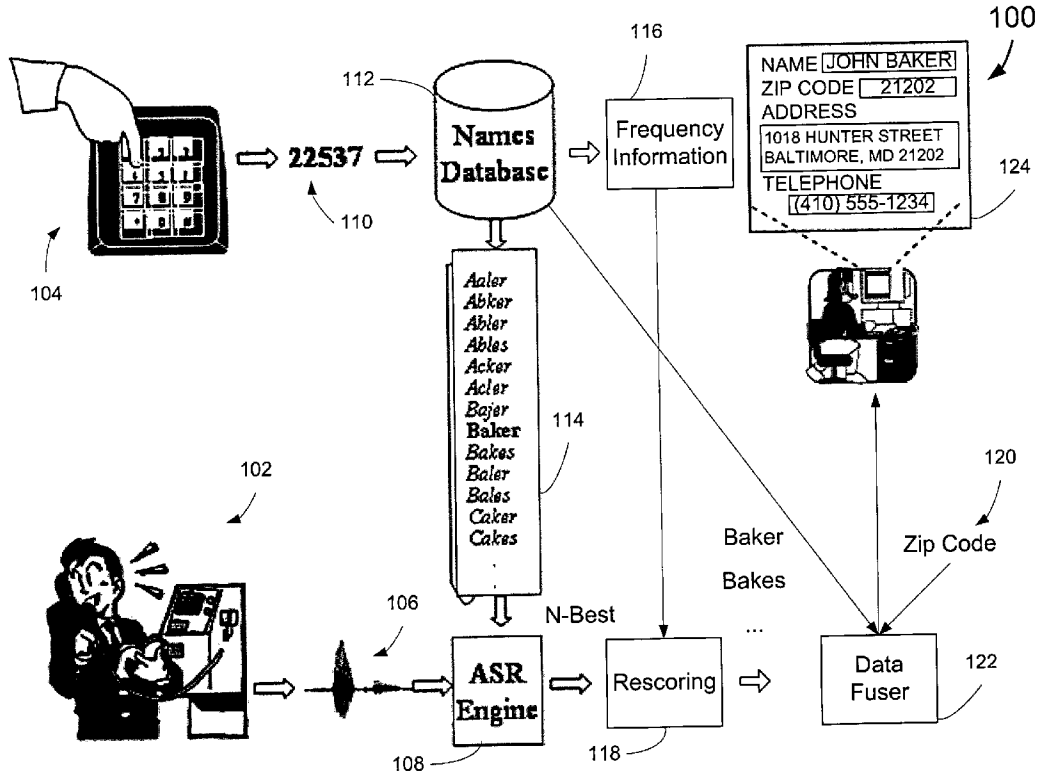
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(57) ABSTRACT

An automated form filling system includes an input receptive of a plurality of information inputs from a plurality of information sources. An information fuser is operable to select information from the plurality of information inputs based on a comparison of the information inputs, and based on knowledge relating to reliability of the information sources. A form filler is operable to fill an electronic form with the selected information.



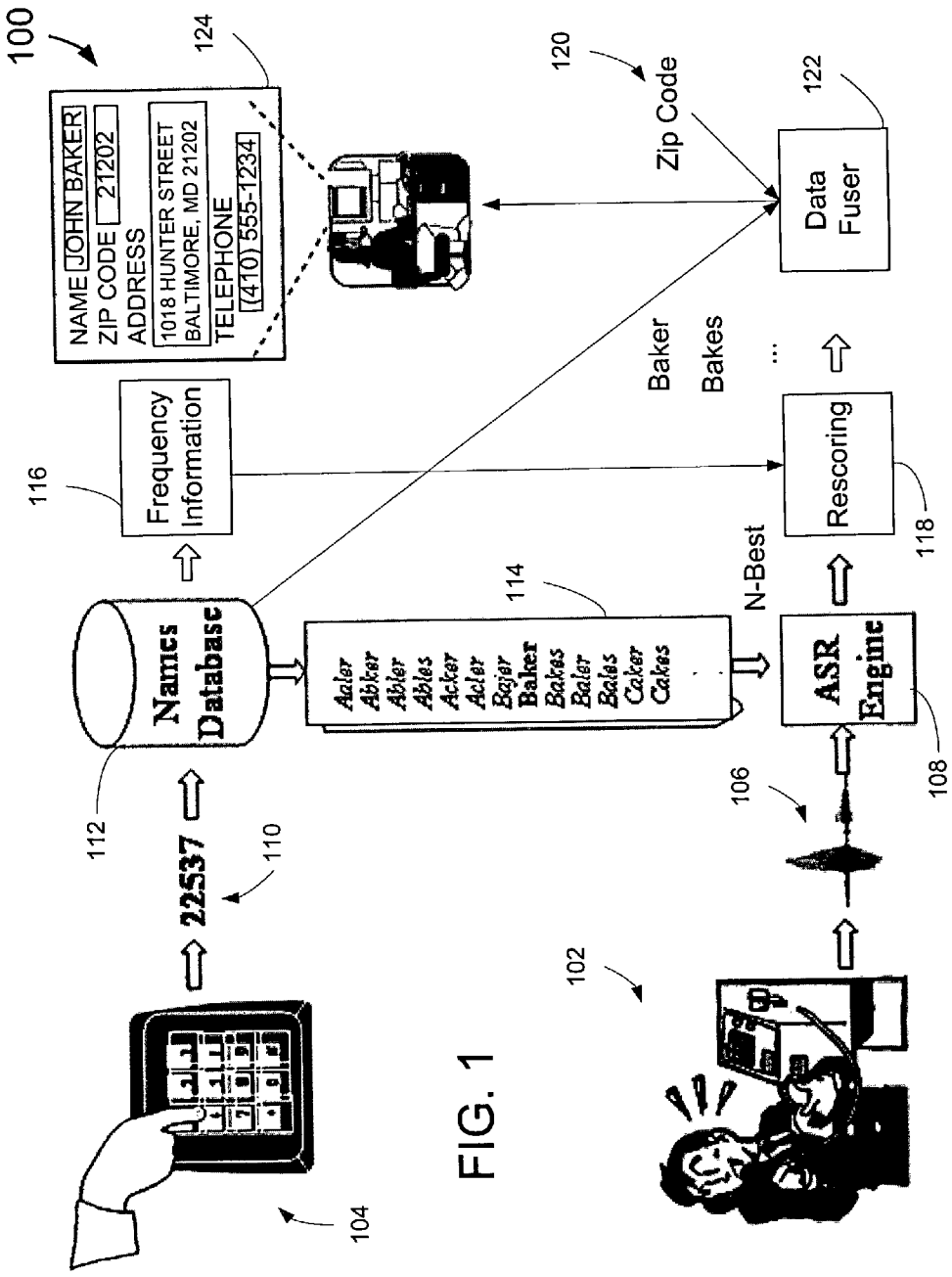

100
124
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1018 HUNTER STREET
BALTIMORE, MD 21202
TELEPHONE
(410) 555-1234
120
Zip Code
122
Data Fuser
Baker
Bakes
...
116
Frequency Information
Rescoring
118
N-Best
114
Aaler Abker Abler Ables Acker Acler Bajer Baker Bakes Baler Bales Caker Cakes
Names Database
ASR Engine
108
106
112
22537
110
102
104

FIG. 1

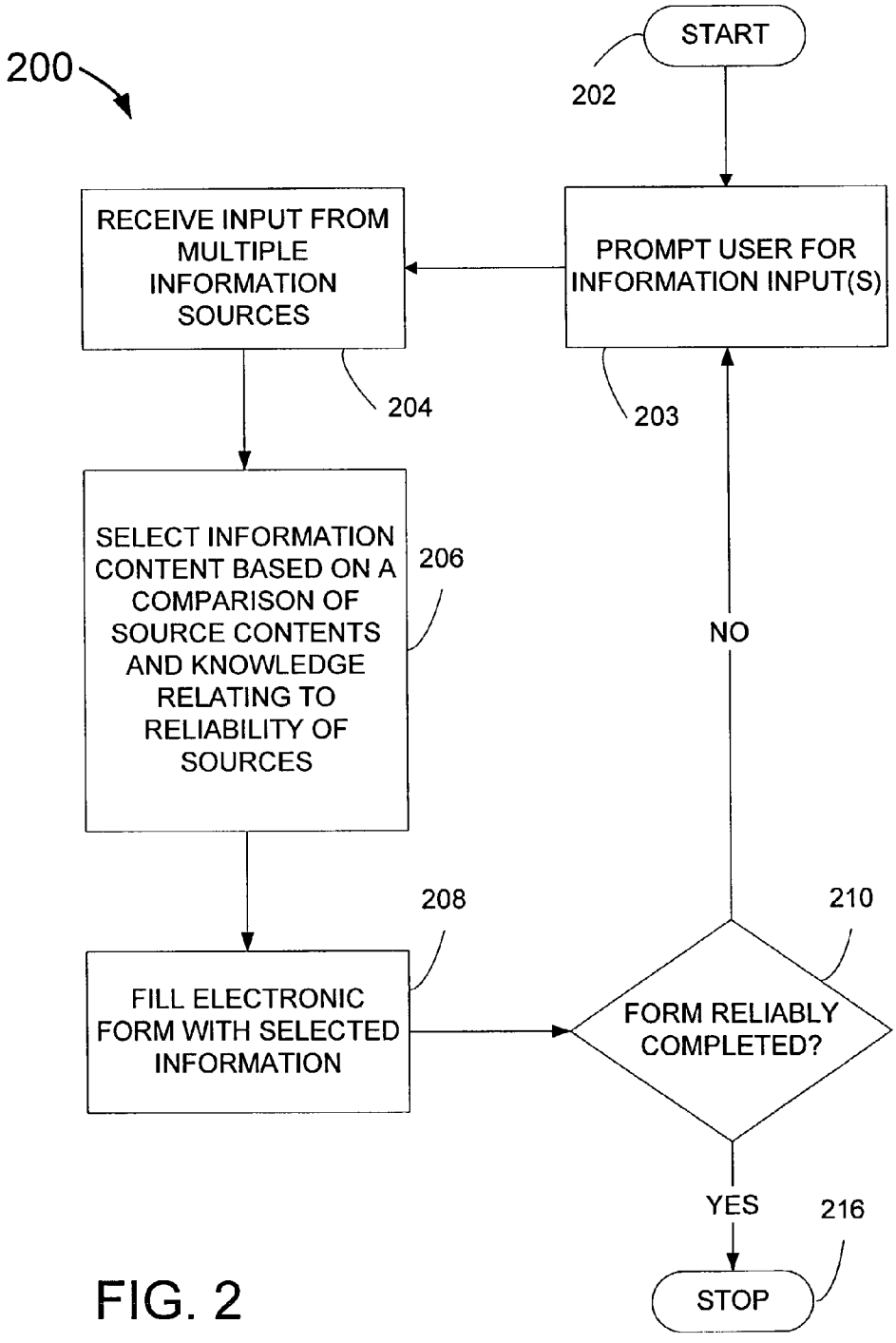

200
START
202
PROMPT USER FOR INFORMATION INPUT(S)
203
RECEIVE INPUT FROM MULTIPLE INFORMATION SOURCES
204
SELECT INFORMATION CONTENT BASED ON A COMPARISON OF SOURCE CONTENTS AND KNOWLEDGE RELATING TO RELIABILITY OF SOURCES
206
FILL ELECTRONIC FORM WITH SELECTED INFORMATION
208
FORM RELIABLY COMPLETED?
210
NO
YES
STOP
216

FIG. 2

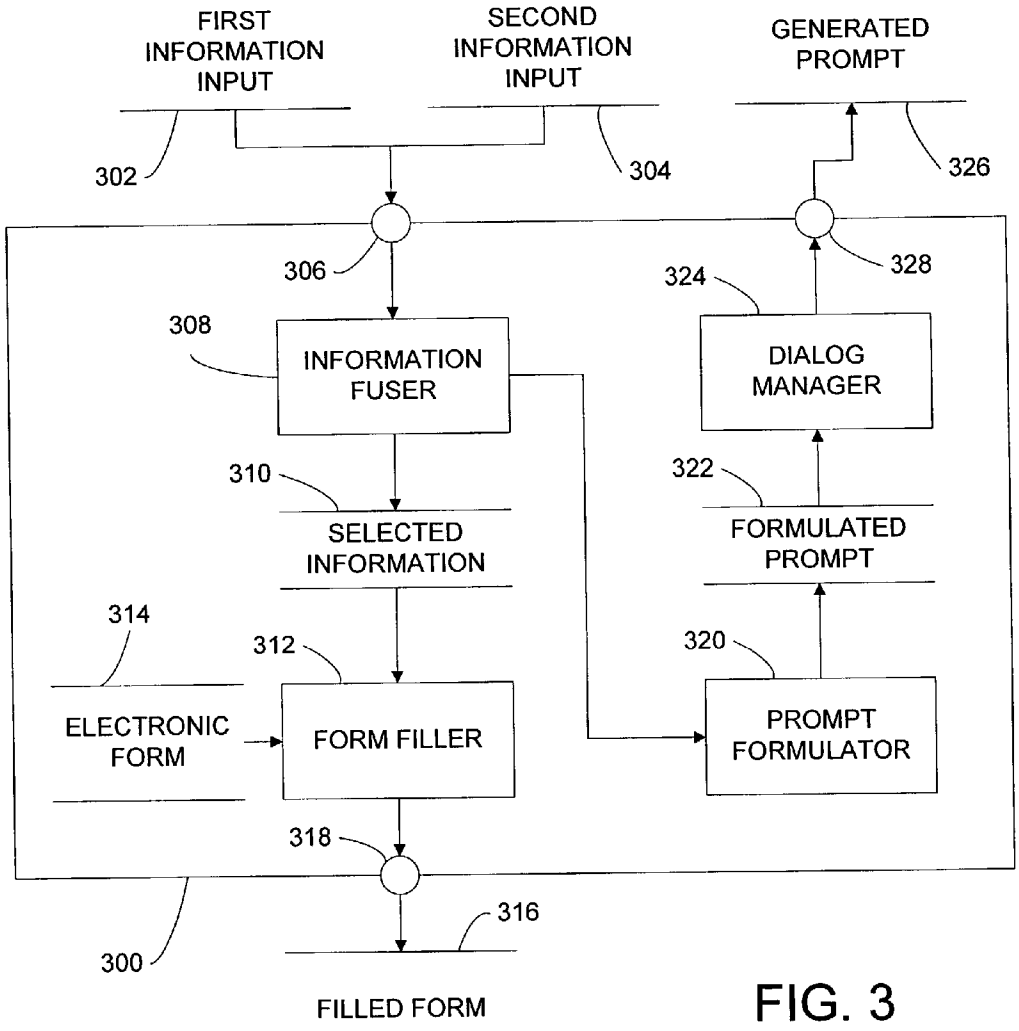

FIRST INFORMATION INPUT
SECOND INFORMATION INPUT
GENERATED PROMPT
302
304
326
306
328
324
308
INFORMATION FUSER
DIALOG MANAGER
310
322
SELECTED INFORMATION
FORMULATED PROMPT
314
312
320
ELECTRONIC FORM
FORM FILLER
PROMPT FORMULATOR
318
316
300
FILLED FORM

FIG. 3

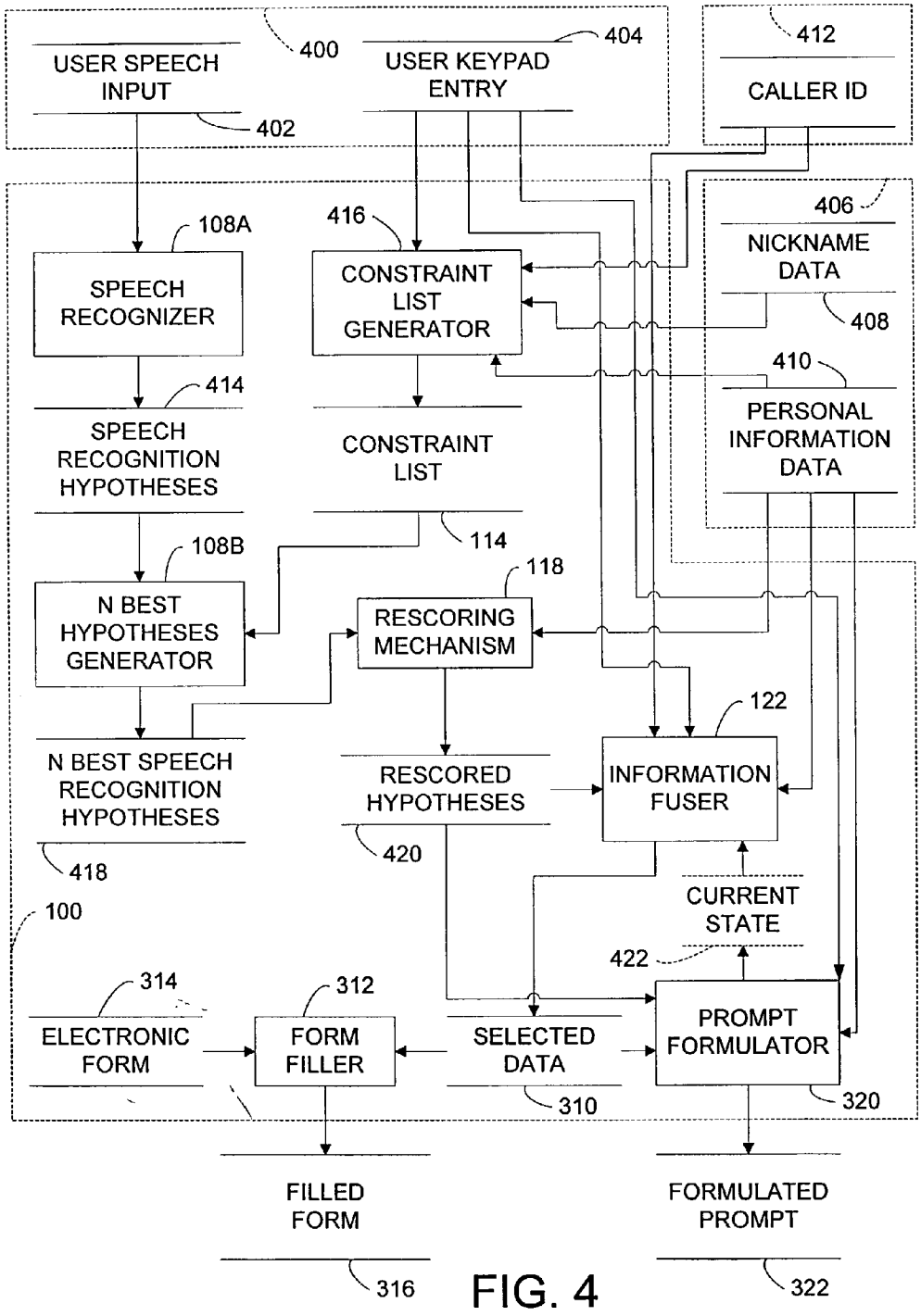

400
USER SPEECH INPUT
402
404
USER KEYPAD ENTRY
412
CALLER ID
406
NICKNAME DATA
408
410
PERSONAL INFORMATION DATA
108A
SPEECH RECOGNIZER
416
CONSTRAINT LIST GENERATOR
414
SPEECH RECOGNITION HYPOTHESES
CONSTRAINT LIST
114
108B
N BEST HYPOTHESES GENERATOR
118
RESCORING MECHANISM
122
N BEST SPEECH RECOGNITION HYPOTHESES
418
RESCORED HYPOTHESES
420
INFORMATION FUSER
CURRENT STATE
422
100
314
ELECTRONIC FORM
312
FORM FILLER
SELECTED DATA
310
PROMPT FORMULATOR
320
FILLED FORM
316
FORMULATED PROMPT
322

FIG. 4

SYSTEM AND INTERACTIVE FORM FILLING WITH FUSION OF DATA FROM MULTIPLE UNRELIABLE INFORMATION SOURCES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 10/022,023 filed on Dec. 13, 2001. The disclosure of the above application is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention generally relates to speech recognition and particularly relates to automated form filling over a telephone system.

BACKGROUND OF THE INVENTION

[0003] Automatic electronic form filling by a user, particularly over a telephone system, is a notoriously laborious and error prone process. Use of numerical keypad entries to attempt retrieval of user information is one existing process that proves to be only as reliable as completeness and correctness of the user information database and user knowledge of the required information and successful operation of the telephone keypad. Other applications, such as confirming availability and/or delivery of a product over the phone or on a networked computer system, suffer from similar problems.

[0004] The key to improving the automated form filling process, by increasing reliability of information and decreasing effort on the part of a user, involves recognizing that information from multiple information sources can be fused in an intelligent manner. To be successful, the information fusion process should not trust the information sources to be reliable, and should intelligently use information from the multiple sources to constrain and supplement one another based on differences in reliability between sources and of particular information inputs. To be further successful, the fusion process should be able to incorporate a dialogue with a user to increase knowledge relating to reliability of information content, and/or gather additional information inputs.

[0005] Automated form filling processes do not currently succeed in intelligently fusing information from multiple information sources based on knowledge relating to differences in reliability information form different sources, thereby simultaneously increasing reliability of form contents and decreasing effort on the part of the user. The need remains, therefore, for a solution to the problems associated with automated form filling as detailed above. The present invention provides such a solution.

SUMMARY OF THE INVENTION

[0006] In accordance with the present invention, an automated form filling system includes an input receptive of a plurality of information inputs from a plurality of information sources. An information fuser is operable to select information from the plurality of information inputs based on a comparison of the information inputs, and based on knowledge relating to reliability of the information sources. A form filler is operable to fill an electronic form with the selected information.

[0007] The form filling system of the present invention is advantageous over previous form filling systems in that it has knowledge relating to reliability of multiple information sources and is able to compare and select information content accordingly. It is further advantageous in its further aspects, wherein a prompt formulator is capable of formulating a prompt based on a comparison of the information content of the sources, and based on a level of knowledge relating to reliability of the source content, wherein the formulated prompt is designed to elicit a response from a user operable to increase knowledge of reliability relating to the multiple information sources. A resulting dialog with a user succeeds in filling out an electronic form while simultaneously decreasing effort on the user's part and increasing reliability of the form contents.

[0008] The present invention is particularly suitable for use with electronic form filling over a telephone, wherein user input and accessible databases are unreliable information sources. Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0010] **FIG. 1** is an illustrated block diagram depicting a general implementation of the present invention with a telephone call center;

[0011] **FIG. 2** is a flow chart depicting the method of the present invention;

[0012] **FIG. 3** is a block diagram depicting a form filling system according to the present invention; and

[0013] **FIG. 4** is a partial block and information flow diagram depicting a detailed implementation of the present invention with a telephone call center.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. In a preferred embodiment, the present invention is employed to perform form filling by fusing multimodal user input over a telephone with one or more user information databases. The form filling system **100** of **FIG. 1** exemplifies one implementation of the preferred embodiment of the present invention to fill out a form requiring a user's name, address, and telephone number.

[0015] According to form filling system **100**, a user, one Mr. Baker, is initially prompted to speak his name into the telephone receiver as at **102**, and to spell his name via the telephone keypad as at **104**. The speech input **106** is communicated to an automatic speech recognizer **108**, whereas the keypad entry **110** is communicated to an information database **112** of names indexed by predefined classes defined

by the telephone keypad. In turn, a constraint list **114** of candidate names is generated from the keypad entry **110** and the information database **112** of names, and the generated constraint list **114** is further communicated to the speech recognizer **108**. The speech recognizer functions to recognize the speech input **106** by generating a plurality of speech recognition hypotheses, and then selects the N best generated hypotheses by comparing them to the constraint list **114**. Thus, if "Bater" were one of the original speech recognition hypotheses, it would be discarded based on it's absence from the constraint list.

[**0016**] The information database **112** further serves as an information source having the names and addresses of most residents of the nation in which the user, Mr. Baker, is located, so frequency information **116** relating to the frequency with which names appear in the database can be communicated to rescoring module **118** used to further rescore the N best speech recognition hypotheses. Thus, if "Baker" and "Bakes" are both present in the N best speech recognition hypotheses, they can be rescored to increase the ranking of "Baker" with respect to the ranking of "Bakes" based on a higher frequency of "Baker" in the information database **112** compared to the frequency of "Bakes".

[**0017**] The user is additionally prompted to enter his or her postal code, such as a zip code, and the received postal code **120**, the rescored speech recognition hypotheses, and the information database **112** are communicated to an information fuser **122**. The information fuser **122**, in turn, selects information content of the information database **112** based on the rescored recognition hypotheses and the received zip code **120**. The information fuser **122**, however, does not merely trust the database **112**, the rescored hypotheses, and the received zip code **120** to be accurate. Instead, the information fuser **122** recognizes and adjusts for several potential causes of unreliability.

[**0018**] The data communicated to information fuser **122** may be unreliable for several reasons. For example, the user's name may be spoken in such a way that the speech recognition system misrecognizes it. Also, the customer may mistype his or her postal code. Further, the customer database may be incomplete (address missing) or incorrect (name or address misspelled, information out of date). For these and similar reasons, the information fuser employs an information selection strategy that selects the most reliable information available.

[**0019**] The information fuser **122** selects the most reliable information available based on knowledge relating to reliability of various types of information sources, and based on a comparison of the information content from the different sources. For example, if the top-ranking speech recognition hypothesis does not match any name in the information database **112** having the received zip code **120**, but the second-highest ranking speech recognition hypothesis has only a slightly lower score than the top-ranking hypothesis and does match a name in the information database **112** having the received zip code **120**, then the information fuser can select the name indicated by the second-highest ranking speech recognition hypothesis and prompt the user for confirmation. Similarly, if the top-ranking speech recognition hypothesis does not match any name in the information database **112** having the received postal code **120**, but has a much higher score than the second-highest ranking speech recognition hypothesis, then the information fuser **122** can select the name and address matching the highest ranked speech recognition hypothesis and/or prompt the user to reenter the postal code or confirm whether the postal code is correct. Further, the information fuser may take a different approach by distinguishing between an entirely incorrect postal code and one that is only partially incorrect, and further consider the first two digits of the postal code (in the case of a zip code) more reliable than the last three digits of the postal code.

[**0020**] Form filling system **100** preferably has an interviewer **123** for implementing a strategy to prompt the user for input increasing knowledge relating to reliability of information content. The interviewer **123** can be and/or incorporate a human agent to assist in confirming, correcting, selecting, and/or supplementing information. Alternatively, the interviewer **123** can be partially or wholly automated using a prompt formulator to request different inputs from the user in different situations. Accordingly, information fuser **122** can select, deselect, and/or reselect information content based on the increased knowledge relating to the reliability of the information content, and the user responses constitute new information sources to be used in the fusion process. Thus, the prompt formulator can preferably ask the user to supply supplemental information for fields of the form **124** for which reliable information cannot be obtained with the information sources currently available. Form filling system **100** also has a form filler for filling appropriate fields of the electronic form **124** with the selected information content.

[**0021**] The method **200** of the present invention is illustrated in **FIG. 2**, and begins at **202**. Thence, the method **200** proceeds to step **203**, wherein information inputs are sought, preferably by initially prompting a user for specific inputs where a user is an applicable information source. Thence, the method proceeds to step **204**, wherein multiple information inputs are received from multiple information sources. In addition to information inputs provided by a user, these information inputs may also include data from an information database, and/or additional data such as that provided by caller ID or a biometric (measured physical characteristic: fingerprint, retina scan, voice pattern, DNA, etc.) of a user. Thence, the method **200** proceeds to step **206**, wherein information content is selected from one or more of the information sources based on a comparison of source contents and knowledge relating to reliability of the information sources. In one aspect, the knowledge of reliability of a source relates to the type of source, and thus is prior knowledge. In another aspect, however, the knowledge relating to reliability of an information source and/or specific information contents stems from a comparison of the contents of the information sources. Thus, content of an information source of a reliable type may be deemed less reliable based on comparison with content of another information source when the information content conflicts. Similarly, content of an information source of an unreliable type may be deemed more reliable based on comparison with content of another information source when the information content matches. This process can be used to identify more and less reliable portions of information content within one or more information sources.

[**0022**] Once selection of information has taken place, method **200** proceeds to step **208**, wherein an electronic

form is filled with the selected information. If the form is deemed reliably completed as at **210**, then the method ends at **214** and a filled form has been generated. On the other hand, some or all of the selected information may be deemed insufficiently reliable, and/or a sufficient amount of fields of the form may not be deemed completed. In either of these latter cases, method **200** returns to step **203**.

[**0023**] In step **203**, the user is prompted for additional information inputs, and the prompt is designed to elicit a response to increase knowledge of reliability relating to selectable information and/or gather supplemental information. Thus, the request for additional sources may be a request for confirmation of selected information, a request to reenter one of the user inputs, a request for a different information type, or a similar type of request. With this step, speech generation is preferred to communicate the request, especially over a telephone system. Following, the prompt for additional information inputs, the method **200** returns to step **204**, wherein the response is received. The method then proceeds again to step **206**, wherein new information content is selected and/or it is determined whether selected content is reliable based on the new information sources. The method **200** further proceeds to step **208** and fills the form based on the revised selection. If the newly filled form is deemed reliably completed at step **210**, then the method **200** ends at **216**. Otherwise, processing continues in a recursive fashion until a reliably completed form is obtained or the process is otherwise interrupted.

[**0024**] A form filling system **300** of the present invention is more generally illustrated in **FIG. 3**, wherein a first information input **302** from a first information source and a second information input **304** from a second information source are received by input **306** and communicated to information fuser **308**. Information fuser **308** compares and selects information based on reliability of the information as determined based on the comparison and in accordance with predefined rules developed with regard to reliability of different types of information sources and/or information inputs. The selected information **310** is communicated to form filler **312**, which fills an electronic form **314** with the selected information to generate a filled form **316** and communicate it to an outside system via output **316**.

[**0025**] Information fuser **308** mutually communicates with prompt formulator **320**, and prompt formulator **320** formulates a prompt **322** for additional information sources, if needed, based on reliability of the information sources, comparative and/or objective reliability of the available information inputs, and/or requirements for supplemental information content. Prompt formulator **320** further communicates its current state to information fuser **308** so that information fuser **308** is aware of the type of information input(s) requested and how to interpret its information content in view of the other information inputs. The formulated prompt **322** is communicated to a dialogue manager **324** that generates a prompt in a manner communicable to and understandable by a user, preferably by speech generation. The generated prompt is communicated to the user via output **328**. A response from the user constitutes an additional information input communicable to information fuser **308** via input **306**.

[**0026**] A detailed implementation of the present invention with a telephone call center is described with reference to **FIG. 4**. Therein, multi-modal information inputs **400** from an information source corresponding to a user include a user speech input **402** and a user keypad entry **404**. The user speech input includes a spoken user name, and the user keypad entry includes a spelling and/or initials of the user name and a zip code for the user location. Also, textual information inputs **406** from database information sources include nickname data input **408** from a nickname database and personal data input **410** from a personal information database. Use of nickname data input **408** in the present detailed implementation represents an improvement over the more simplified implementation previously discussed with reference to **FIG. 1**. Further, additional data inputs **412** that also represent an improvement include telephone subscriber data **414** provided by a caller ID service. Other examples of additional data inputs **412** that can also be used include biometrics identifying a user and gathered, for example, by a handheld device the user employs to communicate with the call center. Further examples include an IP address for the user location, assuming the user communicates with the call center using a computer network. These types of information inputs all assist to varying degrees in identifying the caller, and the form filling system of the present invention is adapted to use some or all of these types of information inputs accordingly.

[**0027**] Form filling system **100** receives the multi-modal information inputs **400**, textual information inputs **406**, and additional data inputs **412** and uses the various information inputs to constrain and supplement one another according to their varying modalities, utilities, and levels of reliability. For example, user speech input **402** is processed by speech recognizer **108**A to produce a plurality of speech recognition hypotheses **414**. Also, user keypad entry **404**, additional data inputs **412**, nickname data input **408**, and personal data input **410** are all communicated to constraint list generator **416**.

[**0028**] Constraint list generator **416** is adapted in the present implementation to generate a constraint list of candidate names by using a user keypad entry **404** containing a first and last name is used to access the nickname database and generate a plurality of first names based on the input first name, such that a keypad entry generating a constraint list containing "Bob" will also contain "Robert", "Robby", "Bobby", and so on. The plurality of first names thus generated, a zip code from the user keypad entry, and any matching caller ID information are then used to access the personal information database, such as Phonedisc, containing names and addresses of all telephone subscribes in the United States, to generate a constraint list **114** that is communicated to N best hypotheses generator **108**B.

[**0029**] The speech recognition hypotheses **414** are processes by N best hypotheses generator **108**B to generate an N best list of speech recognition hypotheses **418**. One skilled in the art of speech recognition will recognize that an alternative embodiment may be realized with a word lattice. The N best list of speech recognition hypotheses **418** is communicated to rescoring mechanism **118**, as is data from the personal information database pertaining to frequency of appearance of names in the personal information database. Rescoring mechanism **118** rescores the N best list of speech recognition hypotheses **418** to generate a list of rescored hypotheses **420**. Caller ID information and a postal code portion of the user keypad entry **404** may alternatively and/or additionally be used during this process to rescore

hypotheses based on the frequency of names in the database having the corresponding postal code and/or names matching the caller ID information.

[0030] The rescored hypotheses **420**, caller ID information, postal code, and personal data input **410** are communicated to the information fuser **122** and the prompt formulator **320**. The information fuser selects most reliable information from the personal data input **410**, caller ID information, and rescored hypotheses **420**, and the selected data **310** is communicated to the prompt formulator **320** and to form filler **312**. Form filler fills electronic form **314** to produce a filled form **316** that is partially or wholly filled with the selected data. Meanwhile, the prompt formulator **320** determines whether more information is needed based on the selected data, the information available for selection, and requirements of the electronic form. If more information inputs are required, the prompt formulator formulates an appropriate prompt **322** and communicates a current state **422** to information fuser **122**. Otherwise, the form is deemed completed.

[0031] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. For example, one may recognize that information fusion according to the present invention occurs at several levels and at several points in the information selection process. Thus, information fusion is used in generating a constraint list, and in altering confidence scores associated with speech recognition hypotheses. A multi-layered information fusion-based form filling system is thus within the scope of the present invention, and various embodiments may be realized with respect to various types of available inputs, various modalities of input, and various applications of form filling. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. An automated form filling system comprising:

an input receptive of a plurality of information inputs from a plurality of information sources, including a first information input from a first information source and a second information input from a second information source;

an information fuser operable to select information from at least one of the first information input and the second information input based on a comparison of the first information input and the second information input, and based on knowledge relating to reliability of the first information source and the second information source; and

a form filler operable to fill an electronic form with the selected information.

2. The system of claim 1, wherein said information fuser is operable to select information from at least one of the first information input and the second information input based on knowledge relating to reliability of the first information input and the second information input.

3. The system of claim 1 comprising a prompt formulator operable to formulate a prompt designed to elicit a response from a user operable to increase knowledge relating to reliability of selectable information.

4. The system of claim 3 comprising a dialog manager operable to receive the formulated prompt and communicate the formulated prompt to a user in a manner so as to be readily understood by the user.

5. The system of claim 4, wherein said dialog manager operable to generate speech based on the formulated prompt and to communicate the generated speech to the user.

6. The system of claim 3, wherein said prompt formulator includes a human performing a review of at least one of the selected information and the plurality of information inputs, formulating the prompt based on the review, and at least one of confirming and correcting the selected information entered in the filled form based on the elicited responses.

7. The system of claim 3, wherein said prompt formulator is operable to formulate the prompt based on a comparison of the first information input and the second information input, and based on knowledge relating to reliability of the first information source and the second information source.

8. The system of claim 1, wherein the first information source corresponds to the user, and the second information source corresponds to an information database.

9. The system of claim 8, wherein the first information input corresponds to at least one of a user speech input and a user keypad entry.

10. The system of claim 9, wherein the first information input corresponds to the user speech input, wherein said plurality of information inputs includes a third information input from the user, wherein the third information input corresponds to a user keypad entry.

11. The system of claim 1, wherein said information fuser is adapted to yield numerical scores for various portions of information of the second information input based on a comparison of the first information input and the second information input.

12. The system of claim 1, wherein said information fuser is adapted to yield numerical scores for various portions of information of the second information input based on knowledge relating to reliability of various portions of information of the second information input.

13. The system of claim 1, wherein the first information source corresponds to a user, and the first information input corresponds to a measured physical characteristic of the user.

14. The system of claim 1, wherein the first information source corresponds to a user providing the first information input via telephone at a user location, and wherein the second information source corresponds to an automated caller identification system providing at least one of a phone number at the user location and a name associated with the user location.

15. The system of claim 1, wherein the first information source corresponds to a user, and wherein the first information input corresponds to a user handwritten entry.

16. The system of claim 1, wherein the first information source corresponds to a user, the first information input corresponds to a name of a user, the second information source corresponds to a database of names and other personal data of potential users, and the information fuser is operable to make a comparison of the name of the user and the names of potential users, and operable to select at least one of a name and associated personal data from the database based on the comparison.

17. A data fusion-based method of automated form filling comprising:

receiving a plurality of information inputs from a plurality of information sources;

selecting information from the plurality of information inputs based on a comparison of the information inputs and knowledge relating to reliability of the information sources; and

filling an electronic form with the selected information.

18. The method of claim 17, wherein said selecting information from the plurality of information inputs is based on knowledge relating to reliability of the information inputs.

19. The method of claim 17, wherein said receiving a plurality of information inputs from a plurality of information sources corresponds to receiving a user input from a user.

20. The method of claim 19 comprising:

formulating a prompt designed to elicit a new information input from the user; and

prompting the user for the new information input.

21. The method of claim 19, wherein said formulating the prompt includes formulating a prompt designed to elicit a new information input from the user that increases knowledge relating to reliability of selectable information.

22. The method of claim 19, wherein said formulating the prompt includes formulating a prompt designed to elicit a new information input from the user that supplements selectable information.

23. The method of claim 19 comprising selecting unselected information based on the new information input.

24. The method of claim 19 comprising deselecting selected information based on the new information input.

25. The method of claim 19 comprising comparing the new information input to the information inputs previously received.

26. A data fusion-based form filling system for filling an electronic form based on user input communicated over a telephone system, comprising:

an input receptive of personal information input by a user via a telephone system using input speech and a keypad entry;

a speech recognizer operable to recognize the personal information based on the input speech, the keypad entry, and knowledge relating to reliability of the input speech and the keypad entry;

an electronic form filler operable to access a database of stored personal information for potential users, operable to make a comparison between the recognized personal information and the stored personal information, operable to select personal information for the user based on the comparison and based on knowledge relating to reliability of the recognized personal information and the stored personal information, and operable to fill an electronic form with the selected personal information.

27. The system of claim 26 comprising an interviewer operable to prompt the user for additional input required to assist in at least one of:

(a) selecting the personal information;

(b) confirming the selected personal information;

(c) correcting the selected personal information; and

(d) supplementing the selected personal information.

* * * * *