METHOD AND SYSTEM FOR PREDICTING UNDERSTANDING ERRORS IN A TASK CLASSIFICATION SYSTEM

Inventors: Allen Louis Gorin, Berkeley Heights, NJ (US); Irene Langlade Geary, Los Angeles, CA (US); Marilyn Ann Walker, Morristown, NJ (US); Jeremy H. Wright, Warren, NJ (US)

Assignee: AT&T Intellectual Property II, L.P., Reno, NV (US)

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See application file for complete search history.

References Cited
U.S. PATENT DOCUMENTS
4,866,778 A 9/1989 Baker

ABSTRACT
This invention concerns a method and system for monitoring an automated dialog system for the automatic recognition of language understanding errors based on a user’s input communications. The method may include determining whether a probability of understanding the user’s input communication exceeds a first threshold. If the first threshold is exceeded, further dialog is conducted with the user. Otherwise, the user may be directed to a human for assistance. The method also illustratively determines whether the probability also exceeds a second threshold, the second threshold being higher than the first. If so, then further dialog is conducted with the user using the current dialog strategy. However, if the probability falls between a first threshold and a second threshold, the dialog strategy may be adapted in order to improve the chances of conducting a successful dialog with the user.

11 Claims, 6 Drawing Sheets
U.S. PATENT DOCUMENTS

5,666,400 A 9/1997 McAllister et al.
5,675,707 A 10/1997 Gorin et al.
5,794,193 A 8/1998 Gorin
5,860,063 A 1/1999 Gorin et al.
5,905,774 A 5/1999 Tatchell et al.
5,995,664 A* 11/1999 Shimomura ................. 382/329
6,021,384 A 2/2000 Gorin et al.
6,023,673 A 2/2000 Bakis et al.
6,173,261 B1 1/2001 Arai et al.
6,173,266 B1 1/2001 Marx et al.
6,192,110 B1 2/2001 Abella et al.
6,236,968 B1 5/2001 Kanoesky et al.
6,246,986 B1 6/2001 Ammicht et al.
6,269,153 B1* 7/2001 Carpenter et al. ....... 379/88.02
6,324,512 B1 11/2001 Junqua et al.
6,421,655 B1 7/2002 Horvitz et al.
6,681,206 B1 1/2004 Gorin et al.
6,697,782 B1* 2/2004 Iso-Sipila et al. ....... 704/275

OTHER PUBLICATIONS


* cited by examiner
ROUTE/PROCESS THE USER'S COMMUNICATION

INPUT COMMUNICATION FROM THE USER

FIG. 1
FIG. 2

START 2000

RECEIVE RECOGNITION AND UNDERSTANDING DATA BASED ON AN INPUT COMMUNICATION FROM A USER 2100

IS THE PROBABILITY OF CORRECTLY UNDERSTANDING THE USER'S COMMUNICATION ABOVE A PREDETERMINED THRESHOLD? 2200

YES 2400

STORE DIALOG EXCHANGE INTO DIALOG HISTORY DATABASE

NO 2300

ROUTE FOR HUMAN ASSISTANCE

2500

CONDUCT DIALOG TO OBTAIN CLARIFICATION

2600

CAN THE USER'S INPUT BE PROCESSED?

YES

2700

END

NO
FIG. 3

START 3000

RECEIVE RECOGNITION AND UNDERSTANDING DATA BASED ON AN INPUT COMMUNICATION FROM A USER 3100

IS THE PROBABILITY OF CORRECTLY UNDERSTANDING THE USER'S COMMUNICATION ABOVE A FIRST PREDETERMINED THRESHOLD? 3200

YES 3400

STORE DIALOG EXCHANGE INTO DIALOG HISTORY DATABASE

NO 3300

ROUTE FOR HUMAN ASSISTANCE

NO 3500

IS THE PROBABILITY OF CORRECTLY UNDERSTANDING THE USER'S COMMUNICATION ABOVE A SECOND PREDETERMINED THRESHOLD?

YES

CONDUCT DIALOG USING THE CURRENT DIALOG STRATEGY TO OBTAIN CLARIFICATION FROM THE USER 3600

ADAPT THE DIALOG STRATEGY AND CONDUCT DIALOG USING THE ADAPTED STRATEGY TO OBTAIN CLARIFICATION FROM THE USER 3700

NO

CAN THE USER'S INPUT BE PROCESSED? 3800

END 3900
FIG. 5

START

RECEIVE AN INPUT COMMUNICATION FROM A USER

RECOGNIZE PORTIONS OF THE USER'S INPUT COMMUNICATION

CAN THE USER'S INPUT COMMUNICATION BE CORRECTLY UNDERSTOOD SO THAT THE TASK CAN BE CLASSIFIED?

YES

ROUTE ACCORDING TO TASK OBJECTIVE CLASSIFICATION

NO

CONDUCT DIALOG TO OBTAIN CLARIFICATION

STORE DIALOG EXCHANGE INTO DIALOG HISTORY DATABASE

YES

NO

IS THE PROBABILITY OF CORRECTLY UNDERSTANDING THE USER'S COMMUNICATION ABOVE A PREDETERMINED THRESHOLD?

ROUTE FOR HUMAN ASSISTANCE

END
METHOD AND SYSTEM FOR PREDICTING UNDERSTANDING ERRORS IN A TASK CLASSIFICATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application Ser. No. 09/712,194 filed Nov. 15, 2000, now U.S. Pat. No. 6,941,266, and is also a continuation-in-part of U.S. patent application Ser. No. 09/712,192 filed Nov. 15, 2000, now U.S. Pat. No. 7,158,935, and is also a continuation of U.S. patent application Ser. No. 11/219,629 filed Sep. 6, 2005, which was as a continuation of U.S. patent application Ser. No. 09/765,444 filed Jan. 22, 2001 now U.S. Pat. No. 7,003,459.

TECHNICAL FIELD

The invention relates to automated systems for communication recognition and understanding.

BACKGROUND OF THE INVENTION

Today there are many automated dialog systems in operation that serve many purposes, such as for customer care. Because they limit human involvement, such systems save millions of dollars in labor costs. Examples of such systems are shown in U.S. Pat. Nos. 5,675,707, 5,809,063, 6,046,337, and 6,173,261, and U.S. patent application Ser. Nos. 08/943,944, filed Oct. 3, 1997, 09/699,494, 09/699,495, and 09/699,496 all filed Oct. 31, 2000, and 09/712,192 and 09/712,194, both filed Nov. 15, 2000, each of which is incorporated by reference herein in its entirety.

While it has recently become possible to build spoken dialog systems that interact with users in real-time in a range of domains, systems that support conversational natural language are still subject to a large number of language understanding errors. Endowing such systems with the ability to reliably distinguish language understanding errors from correctly understood communications might allow them to correct some errors automatically or to interact with users to repair them, thereby improving the system’s overall performance.

SUMMARY OF THE INVENTION

This invention concerns a method and system for monitoring an automated dialog system for the automatic recognition of language understanding errors based on a user’s input communications. The method may include determining whether a probability of understanding the user’s input communication exceeds a first threshold. The method may further operate such that if the first threshold is exceeded, further dialog is conducted with the user. Otherwise, the user may be directed to a human for assistance.

In another possible embodiment, the method operates as above except that if the probability exceeds a second threshold, the second threshold being higher than the first, then further dialog is conducted with the user using the current dialog strategy. However, if the probability falls between a first threshold and a second threshold, the dialog strategy may be adapted in order to improve the chances of conducting a successful dialog with the user.

This process may be cumulative. In particular, the first dialog exchange may be stored in a database. Then, a second dialog exchange is conducted with the user. As a result, a second determination is made as to whether the user’s input communication can be understood or can be conducted based on the stored first exchange and the current second exchanges. This cumulative process may continue using a third and fourth exchange; if necessary.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in detail with reference to the following drawings wherein like numerals reference like elements, and wherein:

FIG. 1 is a block diagram of an exemplary NLU monitoring system;
FIG. 2 is a flowchart illustrating an exemplary NLU monitoring process;
FIG. 3 is a flowchart illustrating another exemplary NLU monitoring process using dialog strategy adaptation techniques;
FIG. 4 is a block diagram of an exemplary task classification system using a NLU monitoring system;
FIG. 5 is a flowchart illustrating an exemplary task classification process using a NLU monitoring process; and
FIG. 6 is a flowchart illustrating an exemplary task classification process using a NLU monitoring process having dialog strategy adaptation techniques.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Automated dialog systems promise efficient and natural access to a large variety of information sources and services from any communication device, such as telephones, cellular or mobile phones, computers, videophones, etc. Several hundred systems that support system-initiative dialogs are currently being field-tested and deployed. However, systems that support mixed-initiative, conversational, natural language interaction are still subject to a large number of language understanding errors, which have a large impact on the system’s performance.

This invention concerns monitoring an automated dialog system for the automatic recognition of language understanding errors. The ability to recognize and predict language understanding errors will endow an automated system with the ability to correct some errors automatically or to interact with users to repair them.

As an example of the benefit of error detection, contrast the exemplary dialogs below between human users and first, a conventional dialog system, and then a dialog system including the features of the present invention (the phone numbers, card numbers, and pin numbers in the sample dialogs are artificial):

Dialog Failure (Failure to Complete the User’s Intended Task)
S1: AT&T How may I help you?
U1: (silence)
S2: Sorry. Please briefly tell me how I may help you?
U2: I want to find out how much my bill’s worth.
S3: What phone number would you like the call billed to?
U3: Um the access number.
S4: Sorry. Could I have that phone number again?
U4: 1 8 hundred 2 2 5 5 2 8 8.
S5: What number would you like to call?
U5: 800 225 5288 (touchtone input)
S6: Thank you.

The conventional dialog system frequently does not detect that an NLU error has occurred. The conventional dialog system misunderstands the user’s utterance in U2 as a request to make a third-number call. The system continues the dialog.
with utterance S3 by asking which number the user would like to
bill the call to. The dialog ends without completing the user’s task.

Sample Successful Dialog
S1: AT&T How may I help you?
U1: I need to [uh] put a call on my calling card please
S2: May I have your card number, please?
U2: 7 6 5 4 3 2 1 0 9 8 7 6 5 4
S3: What number would you like to call?
U3: 8 1 4 7 7 7 6 6 6 6 (misunderstood)
S4: May I have that number again?
U4: 8 1 4 7 7 7 6 6 6 6
S5: Thank you.

In contrast, the system of the invention completed the
above dialog successfully. Note that after detecting the NLU
error in utterance U3, the system of the invention re-requests
the user to repeat the calling card number in utterance S4.
While the above example illustrates the invention in a
telephone customer care system, this invention may be
applied to any single mode, or multimodal, dialog system.
Furthermore, the invention may apply to any automated rec-
nognition and understanding system that receives communica-
tions from external sources, such as users, customers, ser-
vice providers, associates, etc. Consequently, the method
may operate in conjunction with one or more communication
networks, including a telephone network, the Internet, an
intranet, Cable TV network, a local area network (LAN), a
wireless communication network, etc.

In the discussion below, the term “natural language under-
standing” is used to describe the understanding of any form
of communications received over the networks which may be
expressed verbally, nonverbally, multimodally, etc. Examples
of nonverbal communications include the use of gestures,
body movements, head movements, non-responses, text, key-
board entries, keypad entries, mouse clicks, DTMF codes,
pointers, stylus, cable set-top box entries, graphical user
interface entries, touchscreen entries, etc. Multimodal com-
munications involve communications on a plurality of chan-
nels, such as aural, visual, etc. However, for ease of discus-
sion, examples and discussions of the method and system of
the invention will be discussed below in relation to telephone
systems.

FIG. 1 illustrates an exemplary natural language under-
standing monitoring system 100. The natural language under-
standing monitoring system 100 includes a natural language
understanding (NLU) monitor 180, a dialog manager 190, a
training database 165 and a dialog history database 170. The
NLU monitor 180 receives recognition data from a recognizer
120 and understanding data from a natural language under-
standing (NLU) unit 130 that are based on input communica-
tions from the user.

The recognizer 120 and the NLU unit 130 are shown as
separate units for clarification purposes. However, the func-
tions of the recognizer 120 and the NLU unit 130 may be
performed by a single unit within the spirit and scope of this
invention.

The recognizer 120 and the NLU unit 130 may operate
using one or more of a variety of recognition and understand-
ning algorithms. For example, the recognizer 120 and the NLU
unit 130 may use confidence functions to determine whether
the user’s input communications have been recognized and
understood. The recognition and understanding data from the
user’s input communication are also input into the NLU
monitor 180. Based on this data, the NLU monitor 180 cal-
culates a probability that the language is understood clearly
and this may be used in conjunction with other mechanisms
like recognition confidence scores to decide whether and/or
how to further process the user’s communication.

As a result, if the user’s input communication can be sat-
satisfactorily recognized and understood, the NLU unit 130
routes and/or processes the user’s input communication,
which may include the request, comment, etc. However, if the
NLU unit 180 recognizes errors in the understanding of the
user’s input communication such that it cannot be satis-
factorily recognized and understood, dialog with the user may
need to be conducted. This process will be described in
greater detail below.

In the natural language understanding monitoring system
100, the dialog history database 170 serves as a database for
storing each dialog exchange for a particular dialog. The
training database 165 stores NLU errors collected from inter-
actions with human users and models built based on those
errors, the NLU features identified from the collected dialogs,
and the NLU rules generated from the dialogs and the NLU
features. The NLU monitor 180 exploits the training database
165 by using the dialog history stored in the dialog history
database 170 to predict whether a NLU error is to occur in the
current dialog. While the training database 165 and the dialog
history database 170 are shown as separate databases in the
exemplary embodiments, the dialog history and training data
may be stored in the same database or memory, for example.
This database or memory may be stored external or internal to
the system.

As discussed below, the NLU monitor 180 of the natural
language understanding monitoring system 100 can be
trained to improve its ability to detect errors by exploiting
language understanding errors collected in interactions with
human users and stored in the training database 165. The
initial segments of these dialogs can be used to predict that a
problem is likely to occur. The ability to predict language
understanding errors will allow the system’s dialog manager
190 to apply more sophisticated strategies to repairing
problems, and even perhaps, to prevent them.

Note that the recognizer 120 may be trained to recognize
any number of communication symbols, both acoustic and
non-acoustic, including grammar fragments, meaningful
words, meaningful phrases, meaningful phrase clusters,
superwords, morphemes, multimodal signals, etc., using any
of the methods known to one skilled in the art including those
found in U.S. Pat. Nos. 5,675,707, 5,860,063 and 6,044,337,
and U.S. patent application Ser. Nos. 08/943,944, 09/712,192
and 09/712,194, as discussed above.

In describing the invention, three classes of NLU outcomes
are distinguished: RCORRECT, a correctly understood utter-
ance; RPARTIAL-MATCH, a partially understood utterance;
and RMISMATCH a misunderstood utterance. Experiments
were conducted on learning to automatically distinguish
these three classes of NLU outcomes in 1,787 spoken utter-
ances collected in a field trial system interacting with live
customer traffic.

During the trial, the behaviors of all the system’s 100
components were automatically recorded in a log file and the
dialogs were later transcribed by humans and labeled with
one or more of the categories representing the intended result/
task that the caller was asking the system 100 to perform, on
a per communication basis. This label will be referred to as
the HUMAN-LABEL.

The NLU unit 130 also logged what it believed to be the
correct task category. This label will be referred to as the NLU-
LABEL. One of the focuses of this invention is on the problem
of improving the system’s 100 ability to automatically
detect when the NLU LABEL is wrong. As mentioned above, this ability would allow the system 100 to make better decisions about when to transfer to a human customer care agent, but it might also support repairing such misunderstandings, either automatically or by interacting with a human caller.

The experiments reported here primarily utilize a rule learning program to automatically induce an NLU error classification model from the 11,787 utterances in the corpus. While other learning methods may be used within the spirit and scope of the invention, the experiments and examples discussed below utilized if-then rules that are used to express the learned classification model. For this purpose, if-then rules are easy to understand and would affect the ease with which the learned rules could be integrated back into the system 100.

In this classification, the names of a set of classes to be learned, the names and ranges of values of a fixed set of features, and training data specifying the class and feature values for each example in a training set, were input. As a result, a classification model for predicting the class of future examples was output. For exemplary purposes, the classification model is learned using greedy search guided by an information gain metric, and is expressed as an ordered set of if-then rules.

In application, the utterances in the corpus must be encoded in terms of a set of classes (the output classification) and a set of input features that are used as predictors for the classes. As mentioned above, three classes are distinguished based on comparing the NLU LABEL, the HUMAN LABEL and recognition results for card and telephone numbers: (1) RCORRECT: NLU correctly identified the task and any digit strings were also correctly recognized; (2) RPARTIAL-MATCH: NLU correctly recognized the task but there was an error in recognizing a calling card number or a phone number; (2) RMISMATCH: NLU did not correctly identify the user’s task. The RCORRECT class accounts for 74.81% (64.47%) of the utterances in the corpus. The RPARTIAL-MATCH accounts for 10.0% of the utterances, and the RMISMATCH class accounts for 16.0% of the utterances.

Next, each utterance is encoded in terms of a set of 43 features that have the potential to be used during runtime to alter the course of the dialog. These features were either derived from prior encoding processes or from system 100. The system 100 components that we extracted features from were the recognizer 120, the NLU unit 130, and the dialog manager 190, along with a representation of the discourse history. Because the contribution of different system 100 components to the problem of predicting NLU error rate is to be examined, a classifier that had access to all the features is trained and its performance is compared to classifiers that only had access to recognizer 120 features, to NLU unit 130 features, and to discourse contextual features. Below we describe features obtained from each module.

**Recognizer Features**
- recog, recog-numwords, asr-duration, dtmf-flag, rg-modality, rg-grammar, tempo

**NLU Unit Features**
- a confidence measure for all of the possible tasks that the user could be trying to do
- silence-coverage, inconsistency, context-shift, top-task, nexttop-task, top-confidence, diff-confidence, confertime, saltpertime

**Dialog Manager and Discourse History Features**
- sys-LABEL, uti-id, prompt, reprompt, confirmation, subdial
- discourse history: num-reprompts, num-confirms, num-subdials, reprompt%, confirmation%, subdialog%

The recognizer 120 takes the user’s input communication and produces a transcription. The recognizer 120 features extracted from the corpus were the output of the recognizer 120 (recog), the number of words in the recognizer 120 output (recog-numwords), the duration in seconds of the input to the recognizer 120 (asr-duration), a flag for touchtone input (dtmf-flag), the input modality expected by the recognizer 120 (rg-modality) (one of: none, speech, touchtone, speech+touchtone, touchtone-card, speech+touchtone-card, touchtone-date, speech+touchtone-date, or none-final-prompt), and the grammar used by the recognizer 120 (rg-grammar). A feature called tempo was also calculated by dividing the value of the asr-duration feature by the recog-numwords feature.

The motivation for the recognizer 120 features is that any one of them may have impacted recognition performance with a concomitant effect on language understanding. For example, asr-duration has consistently been found to correlate with incorrect recognition. The name of the grammar (rg-grammar) could also be a predictor of NLU errors since it is well known that the larger the grammar, the more likely a recognizer 120 error is to occur.

One motivation for the tempo feature is that it has been found that users tend to slow down their communication (speech, movement, etc.) when the system 100 has misunderstood them. This strategy actually leads to more errors since the recognizer 120 is not trained on this type of communication. The tempo feature may also indicate hesitations, pauses or interruptions, which could also lead to recognizer 120 errors. On the other hand, additional multimodal input such as touchtone (DTMF) in combination with the user’s communication, as encoded by the feature dtmf-flag, might increase the likelihood of understanding, since the touchtone input is unambiguous and will therefore function to constrain language understanding.

The goal of the NLU unit 130 is to identify what part of the possible results, tasks, etc. the user is attempting, and extract from the user’s communication any items of information that are relevant to completing the user’s intended result (e.g. a phone number is needed for the task dial for me). In this example, fifteen of the features from the NLU unit 130 represent the distribution for each of the 15 possible tasks of the NLU unit’s 130 confidence in its belief that the user is attempting that task. Also included is a feature to represent which task has the highest confidence score (top-task), and which task has the second highest confidence score (nexttop-task), as well as the value of the highest confidence score (top-confidence), and the difference in values between the top and next-to-top confidence scores (diff-confidence).

Other features represent other aspects of the NLU unit 130 processing of the utterance. The inconsistency feature is an intra-utterance measure of semantic diversity, according to a task model of the domain. Some task classes occur together quite naturally within a single statement or request. For example, the dial for me task is compatible with the collect call task, but is not compatible with the billing credit task.

The salience-coverage feature measures the proportion of the utterance that is covered by the salient grammar fragments. For example, this may include the whole of a phone or card number if it occurs within a fragment. The context-shift feature is an inter-utterance measure of the extent of a shift of context away from the current task focus, caused by the appearance of salient phrases that are incompatible with it, according to a task model of the domain.

In addition, similar to the way we calculated the tempo feature, the salience-coverage and top-confidence features are normalized by dividing them by asr-duration to produce the saltpertime and confertime features. The motivation for
these NLU features is to make use of information that the NLU unit 130 has as a result of processing the output of recognizer 120 and the current discourse context. For example, for utterances that follow the first utterance, the NLU unit 130 knows what task it believes the user is trying to complete. The context-shift feature incorporates this knowledge of the discourse history, with the motivation that if it appears that the caller has changed his/her mind, then the NLU unit 130 may have misunderstood an utterance.

The function of the dialog manager 190 is to take as input the output of the NLU unit 130, decide what task the user is trying to accomplish, decide what the system will say next, and update the discourse history. The dialog manager 190 decides whether it believes there is a single unambiguous task that the user is trying to accomplish, and how to resolve any ambiguity.

Features based on information that the dialog manager 190 logged about its decisions or features representing the ongoing history of the dialog might also be useful predictors of NLU errors. Some of the potentially interesting dialog manager 190 events arise due to low NLU confidence levels computed by the NLU monitor 180 that lead the dialog manager 190 to reprompt the user or confirm its understanding. A re-prompt might be a variant of the same question that was asked before, or it could include asking the user to choose between two tasks that have been assigned similar confidence by the NLU monitor 180. For example, in the dialog below the system utterance in S3 counts as a re-prompt because it is a variant of the question in utterance S2.

S1: AT&T How may I help you?
U1: I need credit please.
S2: Okay. What is the reason for the credit?
U2: Miss. uh, Miss, different area code than I needed.
S3: Sorry. I need to know whether you need credit for a wrong number, bad connection or a call that was cut off.
(re-prompt)
U3: It is a wrong number.
S4: What was the number that you dialed?

The features that are extracted from the dialog manager 190 are the task-type label, sys-label, whose set of values include a value to indicate when the system had insufficient information to decide on a specific task-type, the utterance id within the dialog (utt-id), the name of the prompt played to the user (prompt), and whether the type of prompt was a re-prompt (reprompt), a confirmation (confirm), or a subdialog prompt (a superset of the re-prompt and confirmation prompts (subdialog)). The sys-label feature is intended to capture the fact that some tasks may be harder than others. The utt-id feature is motivated by the idea that the length of the dialog may be important, possibly in combination with other features like sys-label. The different prompt features again are motivated by results indicating that re-prompts are frustrating for users.

The discourse history features included running tallies for the number of re-prompts (num-reprompts), number of confirmation prompts (num-confirms), and number of subdialog prompts (num-subdialogs), that had been played before the utterance currently being processed, as well as running percentages (percent-reprompts, percent-confirms, percent-subdialogs). The use of running tallies and percentages is based on showing that normalized features are more likely to produce generalized predictors.

FIG. 2 is a flowchart of an exemplary natural language understanding monitoring process. The process begins its step 2000 and goes to step 2100 where the NLU monitor 180 receives recognition and understanding data from the recognizer 120 and the NLU unit 130, respectively, based on an input communication from a user. In step 2200, the NLU monitor 180 determines the probability of whether the user’s input communication maybe correctly understood based on the initial dialog exchange data based on the recognition and understanding data received and the decision rules stored in the training database 165.

If the probability of correctly understanding the user’s input communication determined by the NLU monitor 180 does not exceed a predetermined threshold, for example, the NLU monitor 180 signals the dialog manager 190 to route the user to a human for assistance. This situation may be represented by the following relationship:

\[1 < \text{P(understanding)}\]

If the probability of correctly understanding the user’s input communication determined by the NLU monitor 180 exceeds the predetermined threshold, for example, the NLU monitor 180 believes that continued dialog may be conducted with the user which may result in successfully routing and/or processing the user’s input communication. This situation may be represented by the following relationship:

\[1 > \text{P(understanding)}\]

As result, the process moves to step 2400 where the NLU monitor 180 stores the dialog exchange into dialog history database 170.

In step 2500, the dialog manager 190 conducts further dialog with the user to obtain clarification of the users initial input communication (exchange 1). In step 2600, if the recognizer 120 and NLU unit 130 can recognize and understand the user’s second input communication (exchange 2) so that it can be processed, the process goes to step 2700 and ends. However, if after exchange 2 the user’s input communication cannot be understood and processed, the process returns to step 2100 where the recognition and understanding data from the user’s second input communication is input to the NLU monitor 180 by the recognizer 120 and the NLU 130. Then in step 2200, the NLU monitor 180 determines the probability of correctly understanding the user’s input communication based on both the current exchange 2 and previous exchange 1 retrieved from the dialog history database 165. The process that continues as stated above.

FIG. 3 is a flowchart of an exemplary natural language understanding monitoring process that allows the dialog strategy to be adapted between dialog exchanges. Steps 3000, 3100, 3200, 3300, and 3400, operate similarly to steps 2000, 2100, 2200, 2300, and 2400 of FIG. 2, respectively, and will not be further discussed.

However, after step 3400 in which the first dialog exchange is stored in the dialog history database 170, in step 3500, the NLU monitor 180 determines whether the probability of correctly understanding the user’s input communication exceeds a second threshold. If the NLU monitor 180 determines that probability of probability of correctly understanding the user’s input communication exceeds the second threshold, in step 3600, the dialog manager 190 conducts dialog with the user using the current dialog strategy. This situation may be represented by the following relationship:

\[1 < \text{P(understanding)} > \text{z/2} \]

However, if the NLU monitor 180 determines that the probability of correctly understanding the user’s input com-
munication does not exceed the second threshold, in step 3700, the dialog manager 190 conducts dialog with the user using an adapted (or different) dialog strategy with the user. This situation may be represented by the following relationship:

\[ 0 < t \leq 2 \]

The process then proceeds to step 3800, where determination is made whether the user's input communication can be processed based on either the current dialog strategy or the adapted dialog strategy opted for in step 3500. The process that continues similar to FIG. 2 above, and as such, will not be discussed further.

FIG. 4 illustrates one possible application of the natural language understanding monitoring system 100. In particular, FIG. 4 shows an exemplary automated task classification system 400 that conducts automated dialog with a user. The automated task classification system 400 includes a classification subsystem 410, a labeled training communications database 450 and a natural language understanding monitoring system 100. The classification subsystem 410 includes a recognizer 420, an NLU unit 430 and a task classification processor 440. The natural language understanding monitoring system 100 includes an NLU monitor 180, a dialog manager 190, a training database 165 and a dialog history database 170, as discussed above.

The automated task classification system 400 is based on the notion of task classification and routing. In the automated task classification system 400, services that the user can access are classified into a plurality of categories by a task classification processor or alternatively, to a category called other for calls that cannot be automated and must be transferred to a human operator. Each category describes a different task, such as person-to-person dialing, or receiving credit for a misdialed number.

The task classification processor 440 determines which task the user is requesting on the basis of the NLU unit's 430 understanding of recognized language segments, stored in the labeled training communications database 450, and recognized by the recognizer 420. The NLU 430 attempts to interpret the user's response to, for example, the open-ended system greeting AT&T, How May I Help You? Once the response has been recognized and understood, task classification processor 440 determines the task, and the information needed for completing the caller's request is obtained using the dialog manager 190. The dialog manager 190 uses sub-modules that are specific for each task.

While the task classification processor 440 and the NLU unit are shown as separate units in FIG. 4, their functions may be performed by a single unit within the spirit and scope of the invention.

FIG. 5 is a flowchart of a possible automated task classification process using the natural language understanding monitoring system 100 of the invention. The process begins at step 5000 and proceeds to step 5100 where an input communication is received by the recognizer 420. At step 5200, the recognizer 420 attempts to recognize portions of the user's input communication, including grammar fragments, meaningful words/phrases/symbols, morphemes, actions, gestures, or any other communication signal.

At step 5300, based on the understanding received from the NLU unit 430, the NLU monitor 180 determines whether the user's input communication can be correctly understood so that the task can be classified. If the task can be classified, then in step 5400, the task classification processor 440 routes the user's request according to the task classification, and the process proceeds to step 5900 and ends.

However, in step 5300, if the NLU monitor 180 determines that the task classification processor 440 cannot classify the user's request, in step 5500, the NLU monitor 180 determines whether the probability of correctly understanding the user's input communication exists above a predetermined threshold.

In this iteration, the NLU monitor 180 is using only the first exchange (exchange 1). The NLU monitor 180 uses the classification model stored in the dialog training database 165 to determine whether the probability of correctly understanding the user's input communication exceeds the predetermined threshold. If the NLU monitor 180 determines that the probability of correctly understanding the user's input communication does not exceed the threshold, then in step 5800 the user is routed to a human for assistance. The process then goes to step 5900 and ends.

If, in step 5500, the NLU monitor 180 determines that the probability of correctly understanding the user's input communication is above the predetermined threshold based on the stored classification model, in step 5600 the first dialog exchange is stored in the dialog history database 170. Then, in step 5700, the dialog manager 190 conducts dialog with the user to obtain further clarification of user's request. The process returns to step 5200 wherein the recognizer 420 attempts to recognize portions of the second exchange with the user. Steps 5300 and 5400 are performed as before using the second exchange.

However, in step 5400, if the task classification processor 440 determines that the task cannot be classified, the dialog predictor 180 gauges the probability of conducting successful dialog above the predetermined threshold based on both exchange 2 and exchange 1 stored in the dialog history database 170. If the probability of conducting a successful dialog does not exceed the predetermined threshold based on exchanges 1 and 2, in step 5800, the task classification processor 440 is instructed by the dialog manager 190 to route the user to a human assistant.

On the other hand, in step 5500, if the NLU monitor 180 determines that the probability of correctly understanding the user's input communication exceeds the predetermined threshold, the second dialog exchange may be stored in step 5600 and further dialog conducted with the user in step 5700. The process would continue using the current and previous exchanges with the user until the task is completed or the user is routed to a human assistant.

FIG. 6 is a flowchart of a possible automated task classification process using the natural language understanding monitoring system 100 with the ability to adapt dialog strategy in an effort to conduct successful dialog with the user. Steps 6000, 6050, 6100, 6150, 6250, 6300, 6350, and 6400 operate similarly to steps 5000, 5100, 5200, 5300, 5400, 5500, 5800, and 5600 of FIG. 5, respectively, and will not be discussed further.

However, after step 6400 in FIG. 6 in which the first dialog exchange is stored in the dialog history database 170, in step 6450, the NLU monitor 180 determines whether the probability of correctly understanding the user's input communication exceeds a second threshold. If the NLU monitor 180 determines that the probability of correctly understanding the user's input communication exceeds the second threshold, in step 6500, the dialog manager 190 conducts dialog with the user using the current dialog strategy.

However, if the NLU monitor 180 determines that the probability of correctly understanding the user's input communication does not exceed the second threshold, in step 6550, the dialog manager 190 conducts dialog with the user using an adapted (or different) dialog strategy with the user.
The process then proceeds to back to step 6050, where the recognizer 120 receives the user’s input communication based on either the current dialog strategy or the adapted dialog strategy opted for in step 6450. The process that continues similar to FIG. 5 above, and as such, will not be discussed further.

The output of each experiment is a classification model learned from the training data that is stored in the training database 165. The model is evaluated in several ways. First, multiple models are trained using different feature sets extracted from different system 100 components in order to determine which feature sets are having the largest impact on performance. Second, for each feature set, the error rates of the learned classification models are estimated using ten-fold cross-validation, by training on a random 10,608 utterances and testing on a random 1,179 utterances 10 successive times. Third, precision, recall and the confusion matrix are recorded in the classifier, and then trained on all the features tested on a random hold-out 20% test set. Fourth, for the classifier trained on all the features, the extent to which the error can be minimized on the error classes RMISMATCH and RPARTIAL-MATCH is examined by manipulating the rule-learning program’s loss ratio parameter. Finally, the results of training other learners are compared on the same dataset with several of the feature sets. The overall accuracy results for detecting NLU errors using the rule-learning program are summarized below (SE=Standard Error).

<table>
<thead>
<tr>
<th>Features Used</th>
<th>Accuracy</th>
<th>(SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE (majority class)</td>
<td>63.47%</td>
<td></td>
</tr>
<tr>
<td>ALL</td>
<td>86.16%</td>
<td>(0.38)</td>
</tr>
<tr>
<td>NLU UNIT ONLY</td>
<td>84.80%</td>
<td>(0.38)</td>
</tr>
<tr>
<td>RECOGNIZER+DISCOURSE</td>
<td>80.97%</td>
<td>(0.26)</td>
</tr>
<tr>
<td>RECOGNIZER ONLY</td>
<td>78.89%</td>
<td>(0.27)</td>
</tr>
<tr>
<td>DISCOURSE ONLY</td>
<td>71.97%</td>
<td>(0.40)</td>
</tr>
</tbody>
</table>

The first line of the above table represents the accuracy from always guessing the majority class (RCORRECT); this is the BASELINE against which the other results should be compared. The first row labeled ALL, shows the accuracy based on using all the features available from the system 100 components. This classifier can identify NLU errors 23% better than the baseline. The second row of the table, NLU ONLY, shows that the classifier based only on the NLU unit 130 features performs statistically as well as the classifier based on all the features. The third row of the table, RECOGNIZER+DISCOURSE shows that combining the RECOGNIZER features with the DISCOURSE features produces a significant increase in accuracy over the use of recognizer 120 features alone, which however still performs worse than the NLU unit 130 features on their own. The last two rows, RECOGNIZER ONLY and DISCOURSE ONLY, indicate that it is possible to do significantly better than the baseline using only the features from the recognizer 120 or from the dialog manager 190 and the discourse history, but these features on their own cannot do as well at predicting NLU accuracy as the NLU unit’s 130 own features based on its own calculations.

Using ten-fold cross-validation, the resulting NLU error classifier can correctly identify whether an utterance is an NLU error 86% of the time, an improvement of 23% over the majority class baseline. In addition, the most important features are those that the NLU unit 130 can compute, suggesting that it will be straightforward to integrate the NLU monitor 180 into the NLU unit 130 of the system 100.

Further results are discussed in Walker et al., “Using Natural Language Processing and Discourse Features to Identify Understanding Errors in a Spoken Dialogue System”, International Conference on Machine Learning, Jan. 31, 2000, incorporated herein by reference in its entirety. As shown in FIGS. 1 and 4, the method of this invention may be implemented using one or more programmed processors. However, method can also be implemented on a general-purpose or a special purpose computer, a programmed microprocessor or microcontroller, peripheral integrated circuit elements, an application-specific integrated circuit (ASIC) or other integrated circuits, hardware/electronic logic circuits, such as a discrete element circuit, a programmable logic device, such as a PLD, PLA, FPGA, or PAL, or the like. In general, any device on which the finite state machine capable of implementing the flowcharts shown in FIGS. 2, 3, 5 and 6 can be used to implement the task classification system and natural language understanding monitoring functions of this invention.

While the invention has been described with reference to the above embodiments, it is to be understood that these embodiments are purely exemplary in nature. Thus, the invention is not restricted to the particular forms shown in the foregoing embodiments. Various modifications and alterations can be made thereto without departing from the spirit and scope of the invention.

The invention claimed is:

1. A method of monitoring natural language understanding of a user’s input communication in a task classification system that operates on a task objective of a user, the method comprising:

a) if the user’s input communication is sufficiently free of natural language understanding (NLU) errors that the user’s input communication can be understood, then making a task classification decision, and

b) if the user’s input communication contains NLU errors that make the user’s input communication not able to be understood, then

i) if a probability of understanding the user’s input communication exceeds a first threshold, conducting further dialog with the user,

ii) otherwise, routing the user to a human for further assistance.

2. The method of claim 1 further comprising:

i) if a probability of understanding the user’s input communication exceeds a second threshold, the second threshold being greater than the first threshold, then conducting further dialog with the user using a current dialog strategy.

3. The method of claim 2 wherein if the second threshold is not exceeded, conducting further dialog with the user using an adapted dialog strategy.

4. The method of claim 3 wherein the adapted dialog strategy includes one of prompting the user with choices and prompting the user to confirm the recognition of NLU errors.

5. The method of claim 1 wherein the probability is determined using recognition of NLU errors derived from the user’s input communication.

6. The method of claim 1 wherein the probability is determined using training data stored in a training database, the training data including at least one of classification models and extracted features.

7. The method of claim 6 wherein the extracted features are derived from recognition, understanding and dialog data.

8. The method of claim 7, further comprising:

storing a first dialog exchange in a dialog history database, wherein the first dialog exchange includes a first auto-
13. The method of claim 8 wherein the method is recursive in that the determining step determines whether the probability of understanding exceeds the first threshold using each of the dialog exchanges conducted.

14. The method of claim 1 wherein the task classification decision includes classifying the task as one of a set of task objectives, and wherein if a task classification decision is made, the user's input communication is routed in accordance with the classified task objective.

15. The method of claim 1 further comprising recognizing portions of the user's input communication; and

providing an input to a language understanding monitor based on applying a confidence function to the recognized portions of the user's input communication.