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(54) **METHODS AND SYSTEMS FOR ADAPTING A SPEECH SYSTEM BASED ON USER CHARACTERISTICS**

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G10L 15/22	(2006.01)
G10L 15/18	(2013.01)
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CPC ***G10L 15/065*** (2013.01); *G10L 15/183* (2013.01); *G10L 15/22* (2013.01)

(58) **Field of Classification Search**

CPC G10L 15/22; G10L 14/183

See application file for complete search history.

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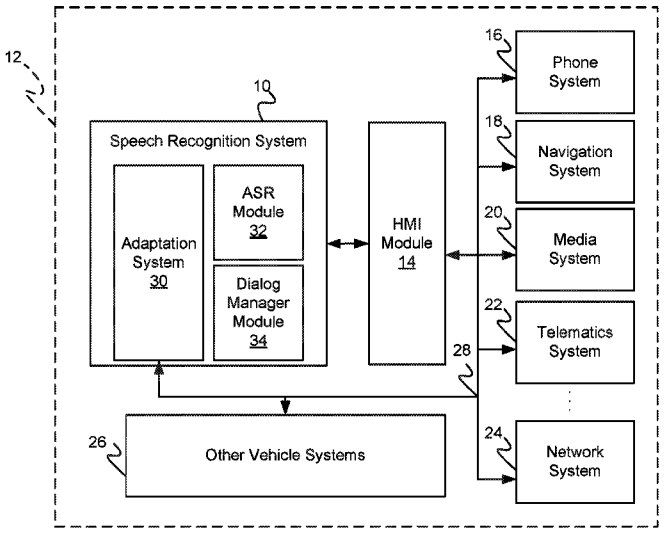
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(57) **ABSTRACT**

Methods and systems are provided for adapting a speech system. In one example a method includes: logging speech data from the speech system; detecting a user characteristic from the speech data; and selectively updating a language model based on the user characteristic.

14 Claims, 10 Drawing Sheets



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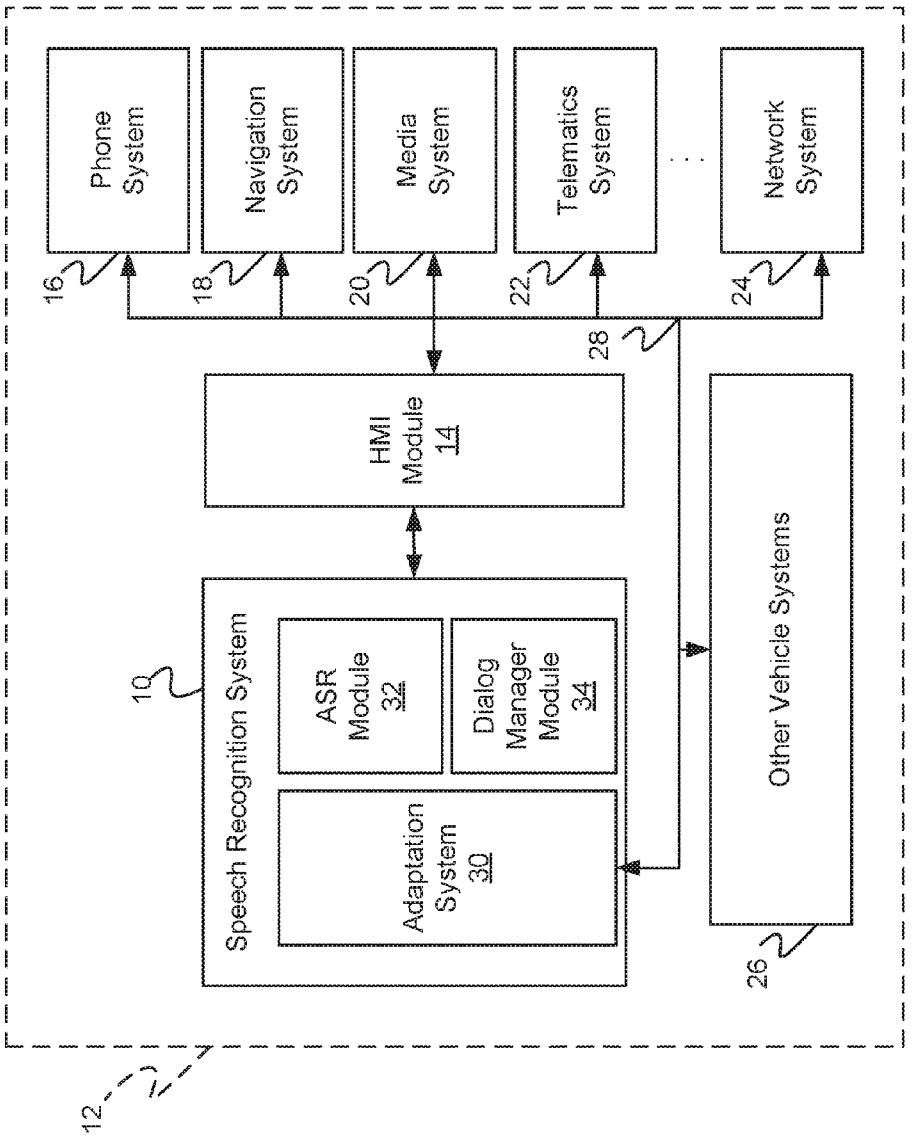

Phone System
Navigation System
Media System
Telematics System
Network System
16
18
20
22
24
28
HMI Module 14
Speech Recognition System
10
ASR Module 32
Dialog Manager Module 34
Adaptation System 30
Other Vehicle Systems
26
12

FIG. 1

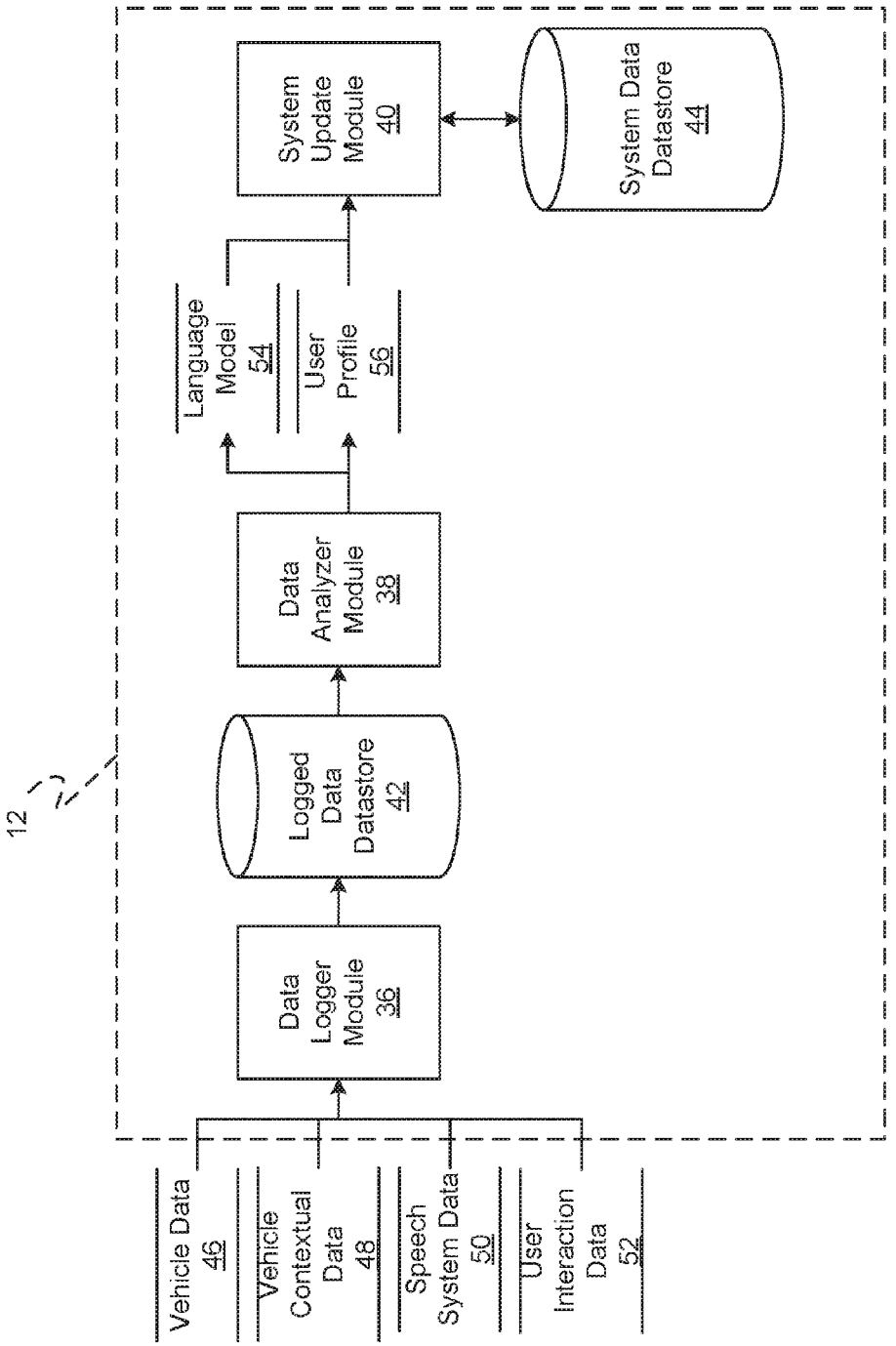

12
Vehicle Data 46
Vehicle Contextual Data 48
Speech System Data 50
User Interaction Data 52
Data Logger Module 36
Logged Data Datastore 42
Data Analyzer Module 38
Language Model 54
User Profile 56
System Update Module 40
System Data Datastore 44

FIG. 2

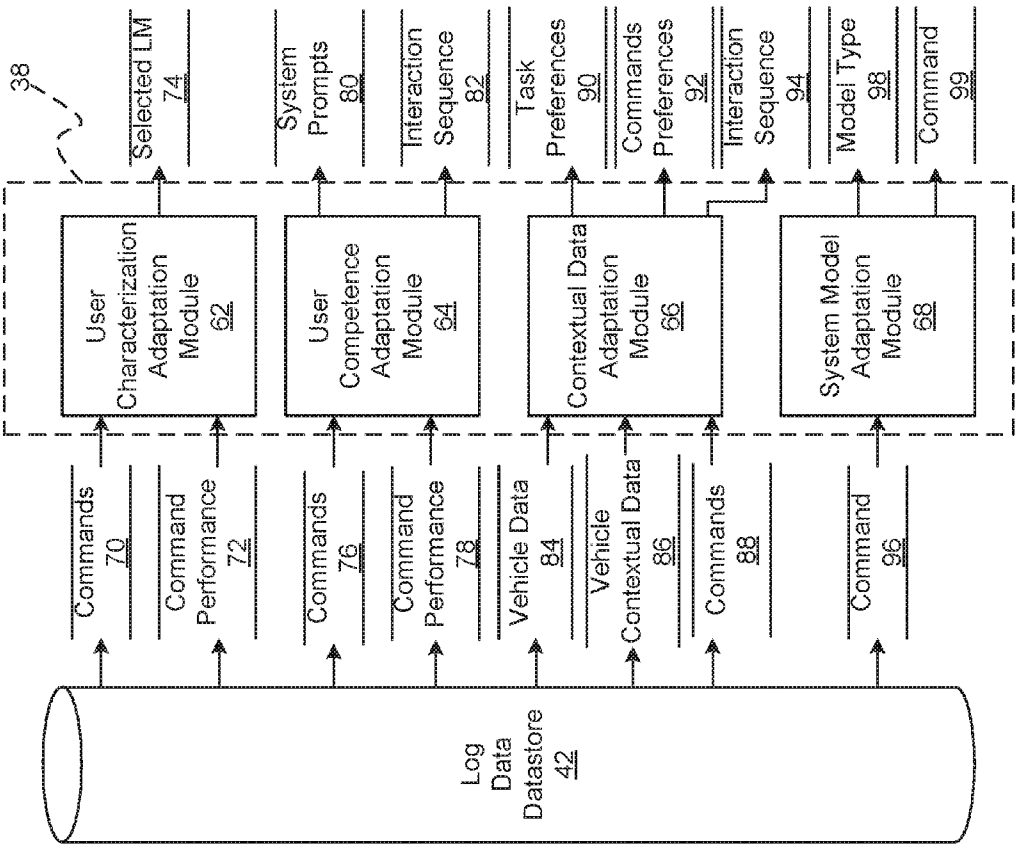

38
Selected LM 74
System Prompts 80
Interaction Sequence 82
Task Preferences 90
Commands Preferences 92
Interaction Sequence 94
Model Type 98
Command 99
User Characterization Adaptation Module 62
User Competence Adaptation Module 64
Contextual Data Adaptation Module 66
System Model Adaptation Module 68
Commands 70
Command Performance 72
Commands 76
Command Performance 78
Vehicle Data 84
Vehicle Contextual Data 86
Commands 88
Command 96
Log Data Datastore 42

FIG. 3

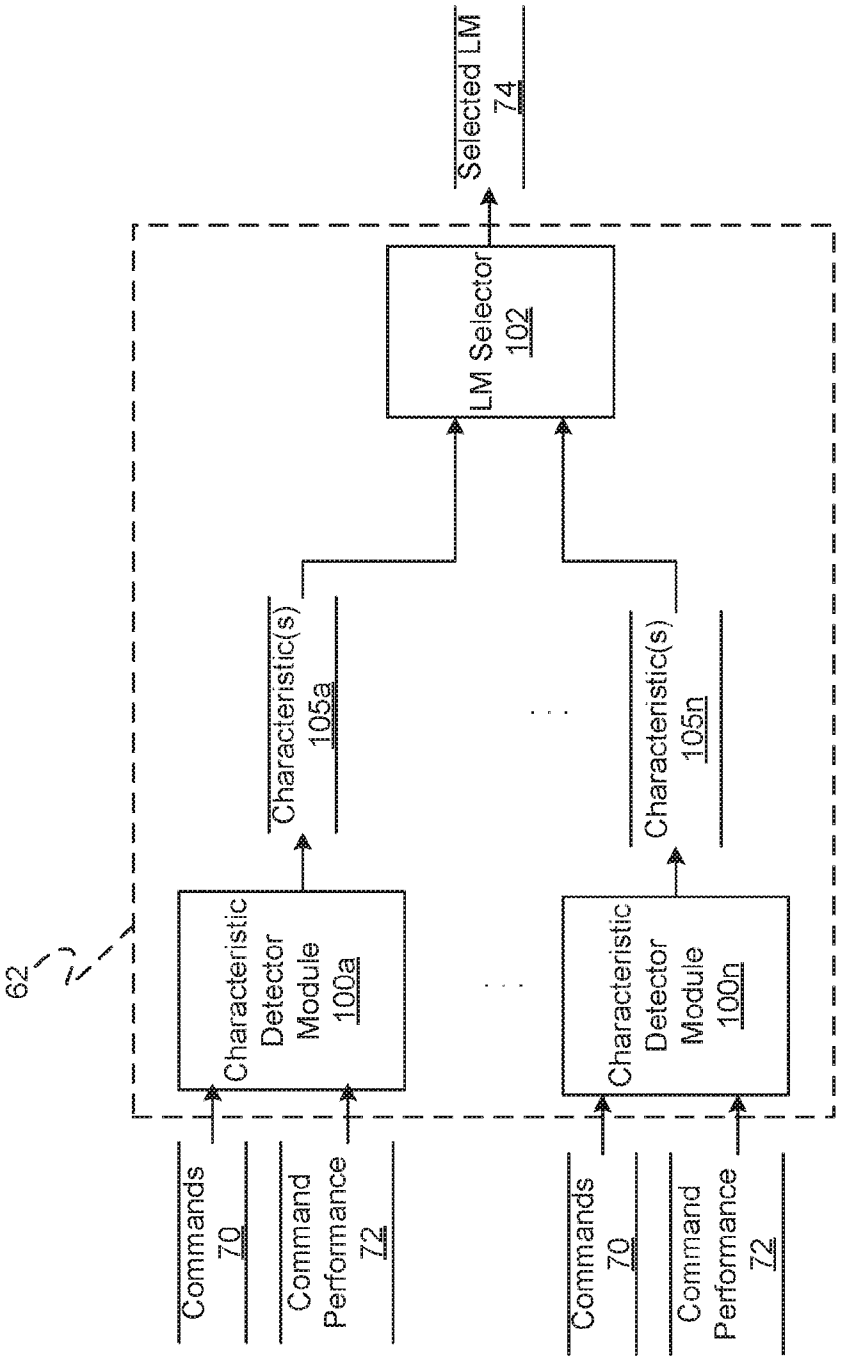

62
Commands 70
Command Performance 72
Characteristic Detector Module 100a
Characteristic(s) 105a
Commands 70
Command Performance 72
Characteristic Detector Module 100n
Characteristic(s) 105n
LM Selector 102
Selected LM 74

FIG. 4

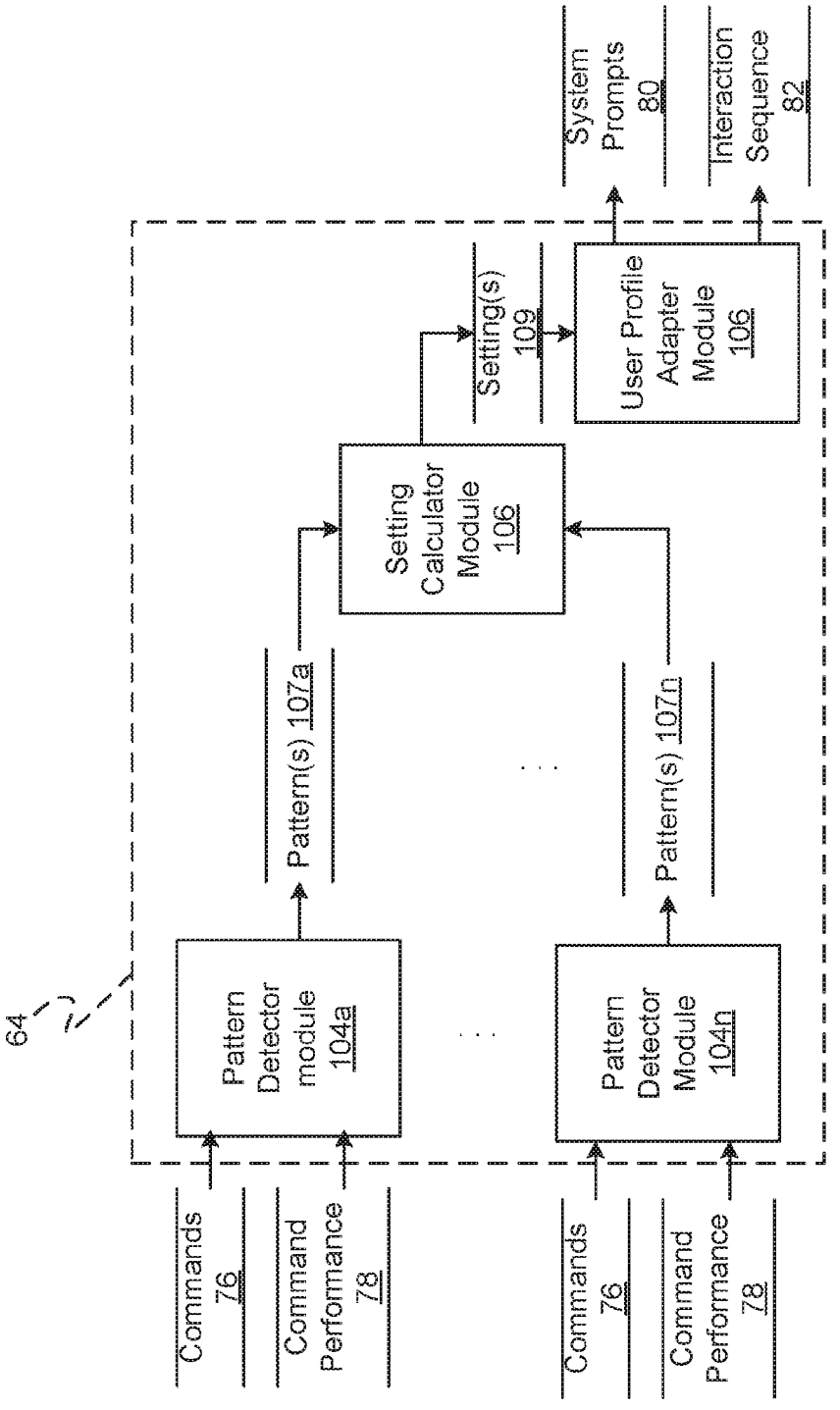

64
Pattern Detector module 104a
Pattern Detector Module 104n
Commands 76
Command Performance 78
Commands 76
Command Performance 78
Pattern(s) 107a
Pattern(s) 107n
Setting Calculator Module 106
Setting(s) 109
User Profile Adapter Module 106
System Prompts 80
Interaction Sequence 82

FIG. 5

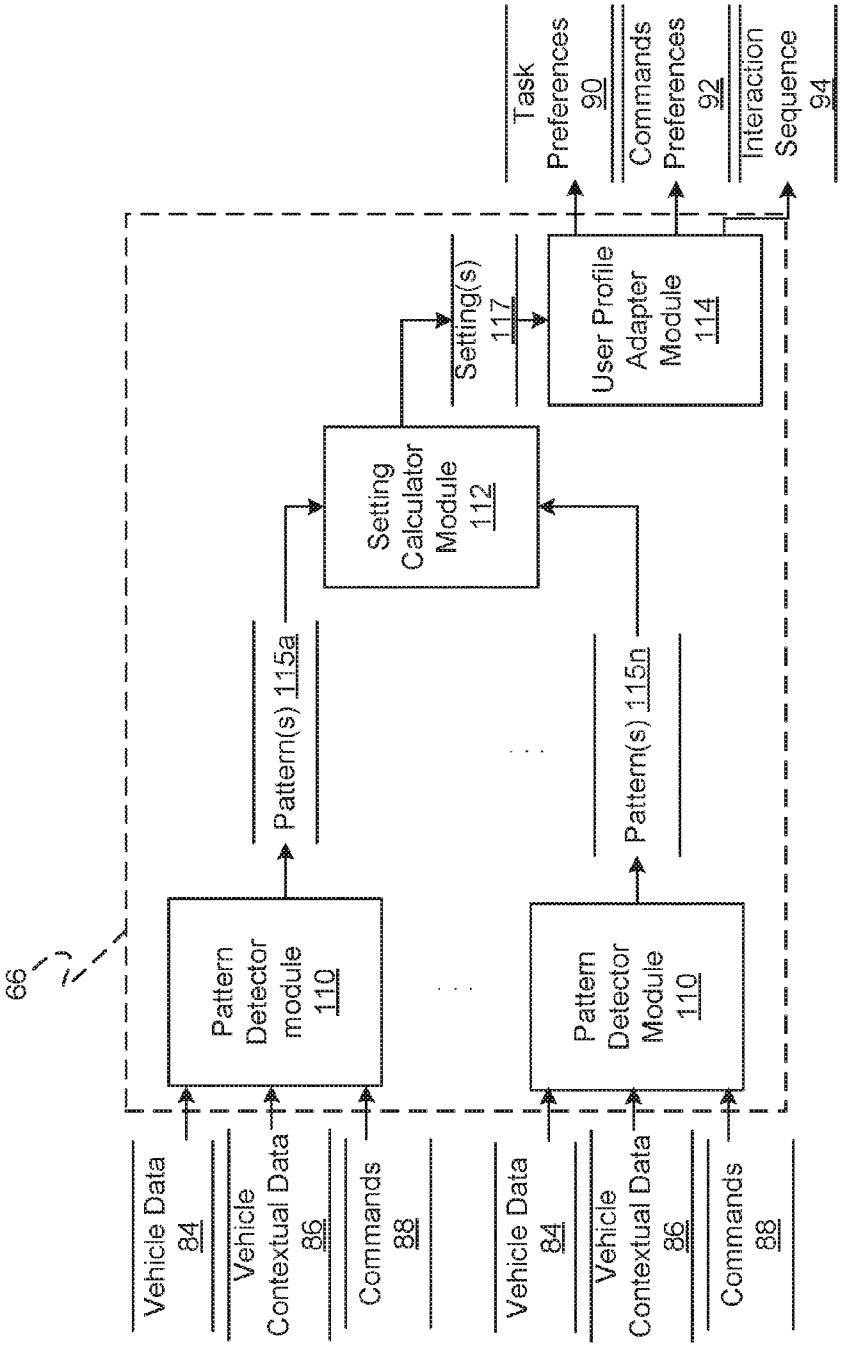

66
Vehicle Data 84
Vehicle Contextual Data 86
Commands 88
Pattern Detector module 110
Pattern(s) 115a
Vehicle Data 84
Vehicle Contextual Data 86
Commands 88
Pattern Detector Module 110
Pattern(s) 115n
Setting Calculator Module 112
Setting(s) 117
User Profile Adapter Module 114
Task Preferences 90
Commands Preferences 92
Interaction Sequence 94

FIG. 6

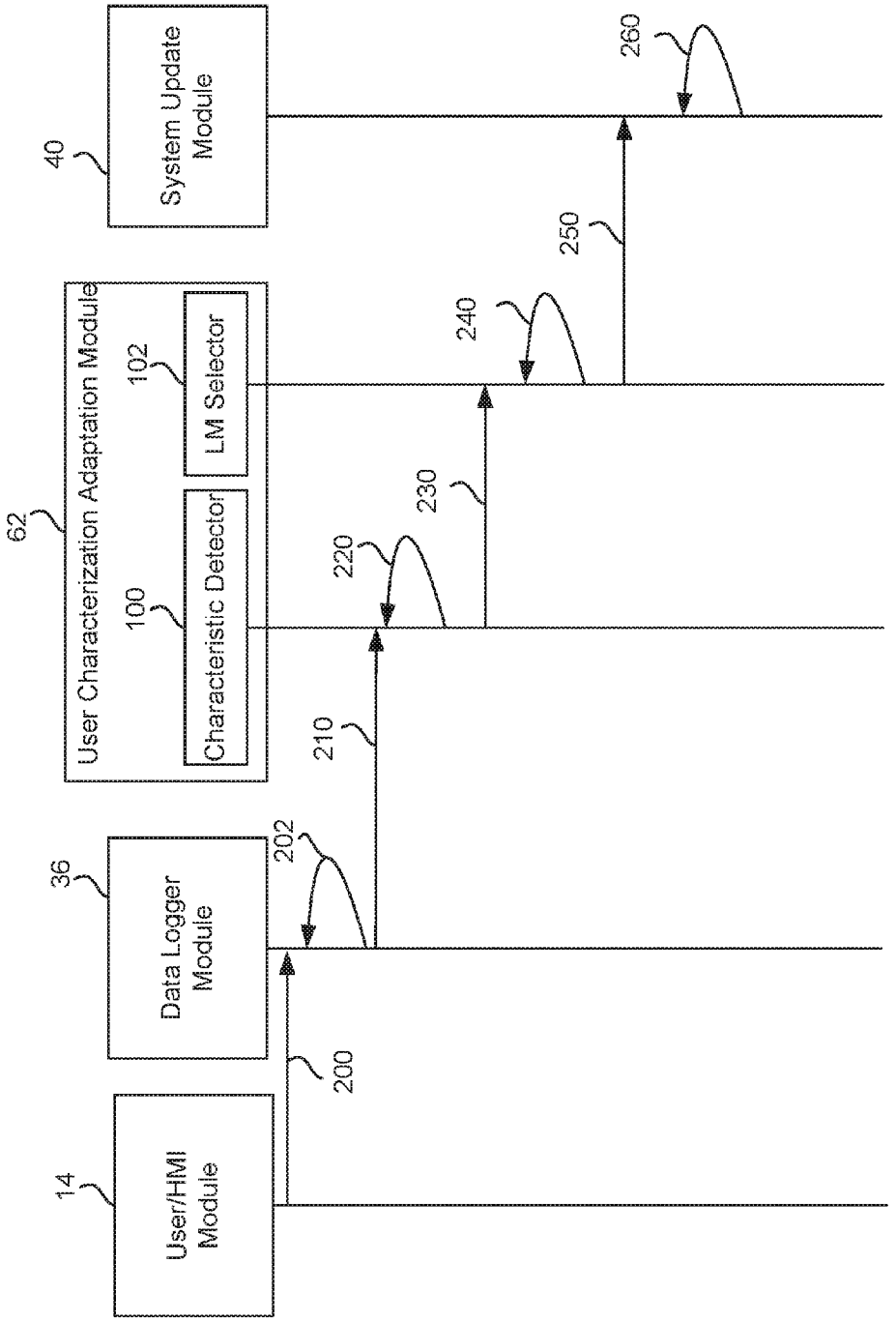

User/HMI Module
14
Data Logger Module
36
User Characterization Adaptation Module
62
Characteristic Detector
100
LM Selector
102
System Update Module
40
200
202
210
220
230
240
250
260

FIG. 7

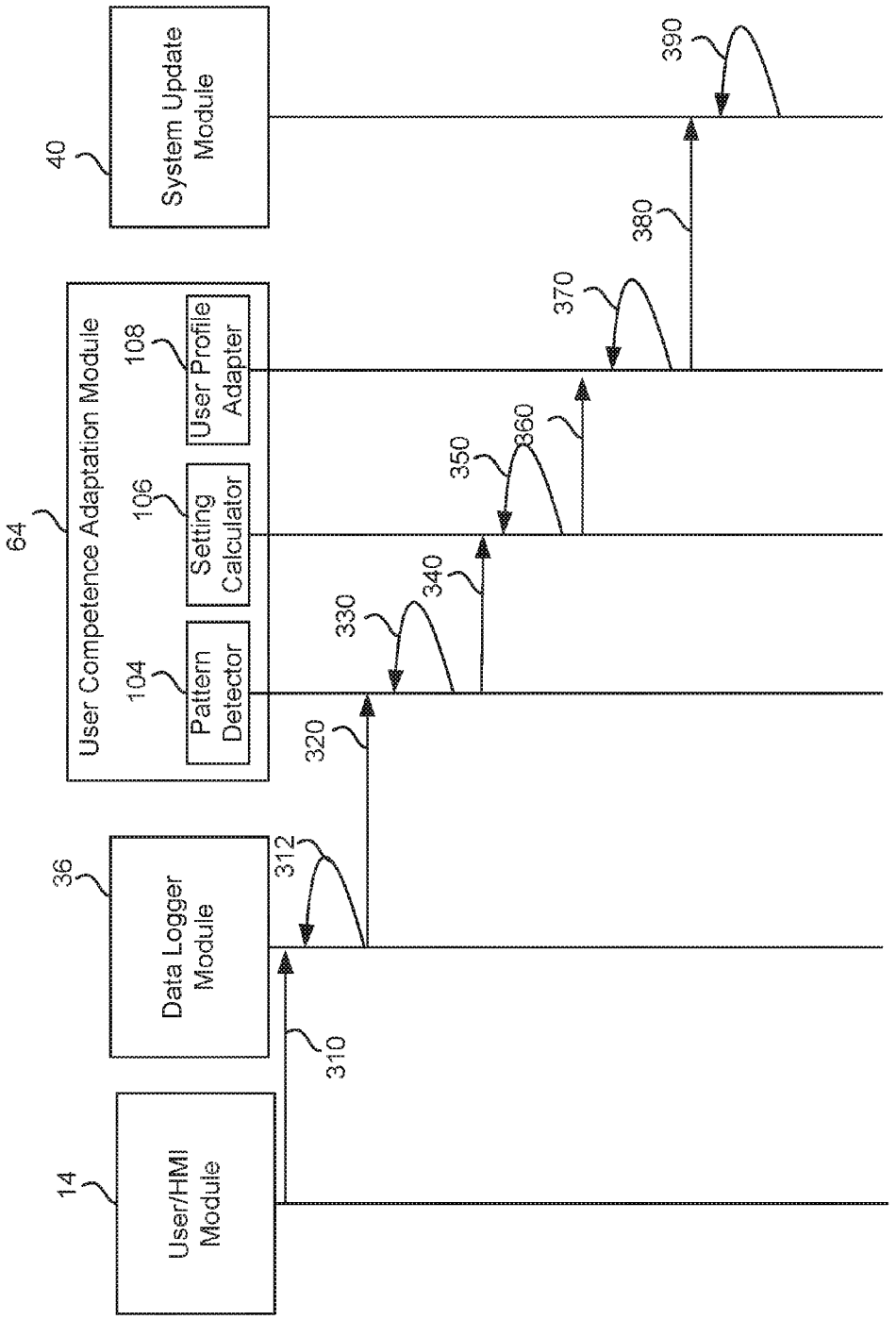

User/HMI Module
14
Data Logger Module
36
User Competence Adaptation Module
64
Pattern Detector
104
Setting Calculator
106
User Profile Adapter
108
System Update Module
40
310
312
320
330
340
350
360
370
380
390

FIG. 8

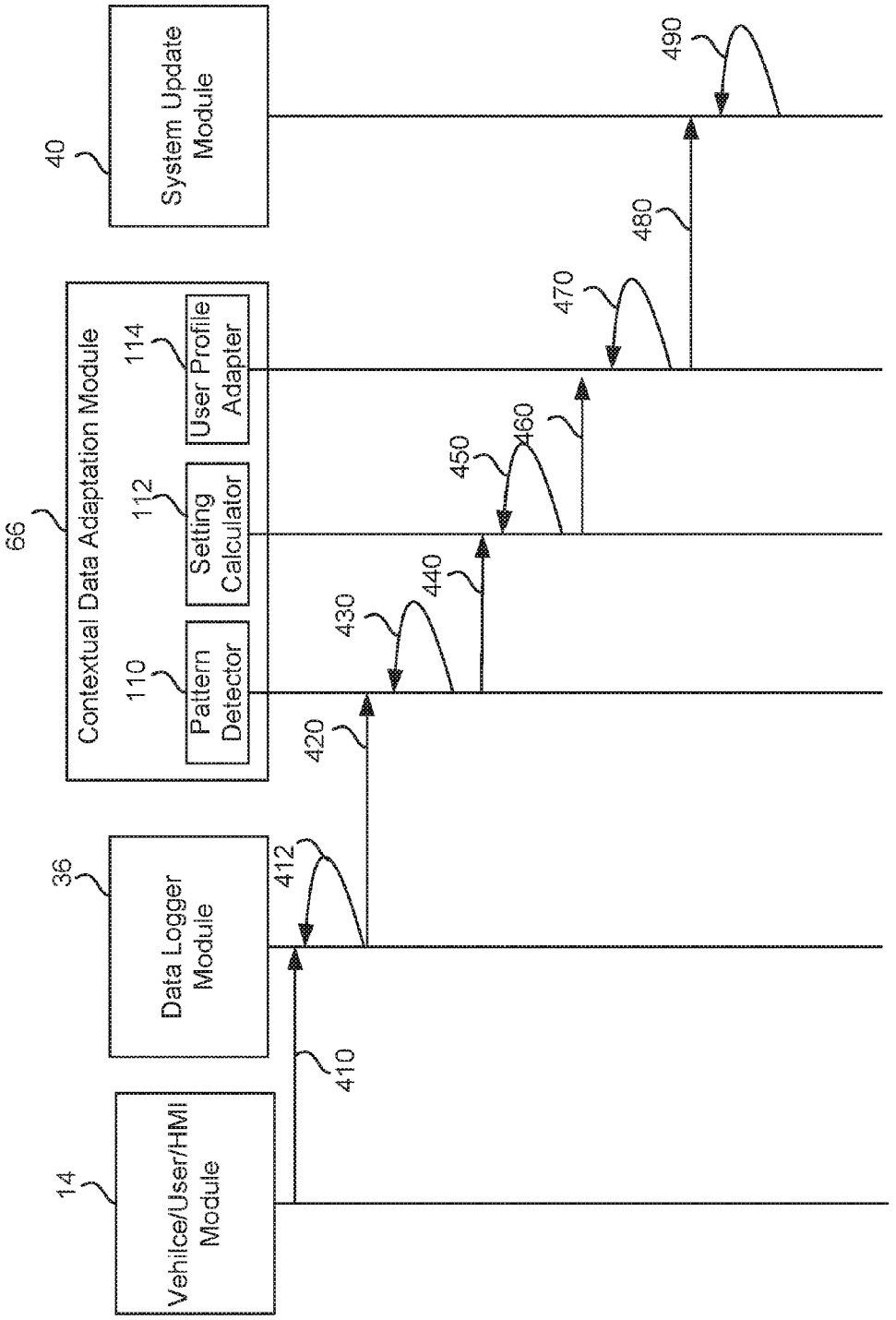

14
Vehicle/User/HMI Module
36
Data Logger Module
66
Contextual Data Adaptation Module
110
Pattern Detector
112
Setting Calculator
114
User Profile Adapter
40
System Update Module
410
412
420
430
440
450
460
470
480
490

FIG. 9

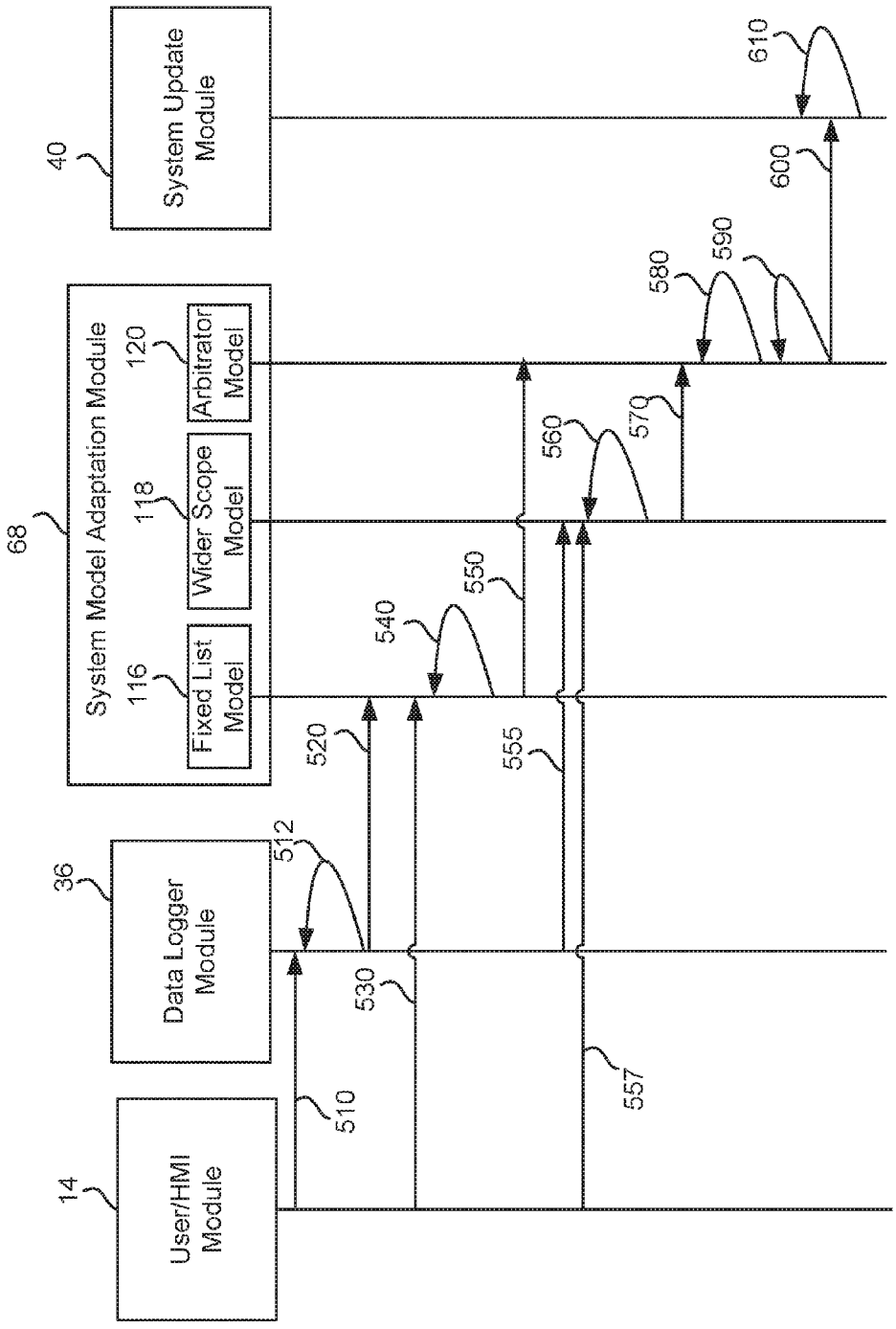

14
User/HMI Module
36
Data Logger Module
68
System Model Adaptation Module
116
Fixed List Model
118
Wider Scope Model
120
Arbitrator Model
40
System Update Module
510
512
520
530
540
550
555
557
560
570
580
590
600
610

FIG. 10

METHODS AND SYSTEMS FOR ADAPTING A SPEECH SYSTEM BASED ON USER CHARACTERISTICS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/725,802 filed Nov. 13, 2012, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The technical field generally relates to speech systems, and more particularly relates to methods and systems for adapting components of speech systems based on data determined from user interactions and/or from one or more systems, for example, of a vehicle.

BACKGROUND

Vehicle speech systems perform speech recognition on speech uttered by an occupant of the vehicle. The speech utterances typically include commands that control one or more features of the vehicle or other systems accessible by the vehicle. The speech systems utilize generic recognition techniques such that speech utterances from any occupant of the vehicle can be recognized. Speech dialog systems manage a dialog with a user of the vehicle based on the commands. The dialog is typically generic for all users.

Accordingly, it is desirable to provide methods and systems for adapting vehicle speech systems based on the occupant of the vehicle and/or the contextual environment of the vehicle and/or the occupant. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

SUMMARY

Methods and systems are provided for adapting a speech system. In one example a method includes: logging speech data from the speech system; detecting a user characteristic from the speech data; and selectively updating a language model based on the user characteristic.

In another example, a system includes a first module that logs speech data from the speech system. A second module detects a user characteristic from the speech data. A third module selectively updates a language model based on the user characteristic.

DESCRIPTION OF THE DRAWINGS

The exemplary embodiments will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

FIG. **1** is a functional block diagram of a vehicle that includes a speech system in accordance with various exemplary embodiments;

FIGS. **2** through **6** are dataflow diagrams illustrating an adaptation module of the speech system in accordance with various exemplary embodiments; and

FIGS. **7** through **10** are sequence diagrams illustrating adaptation methods that may be performed by the speech system in accordance with various exemplary embodiments.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the application and uses. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description. As used herein, the term module refers to an application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

With initial reference to FIG. **1**, in accordance with exemplary embodiments of the present disclosure, a speech system **10** is shown to be included within a vehicle **12**. The speech system **10** provides speech recognition and a dialog for one or more vehicle systems through a human machine interface module (HMI) module **14**. Such vehicle systems may include, for example, but are not limited to, a phone system **16**, a navigation system **18**, a media system **20**, a telematics system **22**, a network system **24**, or any other vehicle system that may include a speech dependent application. As can be appreciated, one or more embodiments of the speech system **10** can be applicable to other non-vehicle systems having speech dependent applications and thus, is not limited to the present vehicle example. For exemplary purposes, the speech system **10** will be discussed in the context of the vehicle example.

The speech system **10** communicates with the multiple vehicle systems **16-24** and/or other vehicle systems **26** through the HMI module **14** and a communication bus and/or other communication means **28** (e.g., wired, short range wireless, or long range wireless). The communication bus can be, for example, but is not limited to, a CAN bus.

Generally speaking, the speech system **10** includes an adaptation module **30**, and automatic speech recognition (ASR) module **32**, and a dialog manager module **34**. As can be appreciated, the ASR module **32** and the dialog manager module **34** may be implemented as separate systems and/or as a combined system as shown. As can further be appreciated, the modules of speech system **10** can be implemented all on the vehicle **12** or part on the vehicle **12** and part on a remote system such as a remote server (not shown).

The ASR module **32** receives and processes speech utterances from the HMI module **14**. Some (e.g., based on a confidence threshold) recognized commands from the speech utterance are sent to the dialog manager module **34**. The dialog manager module **34** manages an interaction sequence and prompts based on the command. The adaptation module **30** logs various speech data and interaction data generated from an occupant of the vehicle (e.g., through the HMI module **14**), logs data from the various vehicle systems **16-24**, and/or logs data from the various other vehicle systems **26** (e.g., that do not include speech applications). The adaptation module **30** performs one or more learning algorithms on the logged data, and adapts one or more components of the speech system **10** based on the learning algorithms. In various embodiments, the adaptation module **30** adapts language models used by the ASR module **32** of the speech system **10**. In various other embodiments, the adaptation module **30** adapts prompts, and interaction sequences used by the dialog manager module **34** of the speech system **10**.

As shown, the adaptation module **30** is included in the speech system **10**. As can be appreciated, in alternative embodiments, the adaptation module **30** may be imple-

mented, for example, in the HMI module **14** or as a stand-alone application that communicates with the speech system **10**. Thus, the disclosure is not limited to the present example.

Referring now to FIG. **2**, a dataflow diagram illustrates the adaptation module **30** in accordance with various embodiments. As can be appreciated, various embodiments of adaptation modules **30**, according to the present disclosure, may include any number of sub-modules. For example, the sub-modules shown in FIG. **2** may be combined and/or further partitioned to similarly adapt portions of the speech system **10** (FIG. **1**).

In various exemplary embodiments, the adaptation module **30** includes a data logger module **36**, a data analyzer module **38**, a system update module **40**, a log data datastore **42**, and a system data datastore **44**. The datastores **42**, **44** may temporarily or permanently store data of the system **10**.

The data logger module **36** logs data from various sources of the vehicle **12** (e.g., the vehicle systems **16-24** and/or the other vehicle systems **26**) in the log data datastore **42**. The data can include, for example, but is not limited to, vehicle data **46**, vehicle context data **48**, speech system data **50**, and user interaction data **52**. The vehicle data **46** can include, for example, speed data, ambient noise level data, passenger data (e.g., a number of passengers detected in the vehicle **12**), vehicle system data (e.g., a number of vehicle systems enabled), etc. The vehicle context data **48** can include, for example, vehicle location data, road type data, weather data, traffic data, etc. The speech system data **50** can include, for example, spoken commands data (e.g., data about commands spoken by an occupant of the vehicle **12**), and performance data (e.g., data about the recognition performance of the spoken commands). The user interaction data **52** can include, for example, interaction sequence data, frequency data of user requests, and data from other HMI modalities, such as touch screen gesture interaction data or display data.

The data analyzer module **38** retrieves the logged data from the log data datastore **42** and analyzes the logged data to determine whether to adapt one or more language models used by the speech system **10**, whether to adapt prompts presented by the speech system **10**, and/or whether to adapt interaction sequences or dialogs provided by the speech system **10**. If it is determined that one or more of the language models, the prompts, and the interaction sequences should be adapted, proposed updates are generated as an updated language model **54**, or as an updated user profile **56** that includes updated prompts and/or updated interaction sequences.

The system update module **40** receives as input the updated language models **54**, and the updated user profile **56**. The system update module **40** stores or updates language models, prompts, and/or interaction sequences from the system data datastore **44** based on the received inputs. For example, if an updated language model **54** is received, the update language model **54** can be combined with an original model to form a more robust language model, for example, by using the smaller language model (i.e. the updated language model **54**) for the shorter history distributions (unigram) and using the more detailed language module (i.e., the stored language module) for the adjusted higher history distribution (trigram). In another example, the user profile **56** including the prompts and/or the interaction sequences can be stored for use with a particular user.

Referring now to FIGS. **3-6**, dataflow diagrams illustrate the data analyzer module **38** of FIG. **2** in accordance with various embodiments. As can be appreciated, various embodiments of data analyzer modules **38**, according to the present disclosure, may include any number of sub-modules. For example, the sub-modules shown in FIGS. **3-6** may be combined and/or further partitioned to similarly analyze the logged data and adapt portions of the speech system **10**. Inputs to the data analyzer module **38** may be retrieved from the log data datastore **42** and/or received directly from the HMI module **14** and/or from one or more of the vehicle systems **16-26**. In various embodiments, the data analyzer module **38** includes a user characterization adaptation module **62**, a user competence adaptation module **64**, a contextual data adaptation module **66**, and/or a system model adaptation module **68**. As can be appreciated, the data analyzer module **38** can only include one of the shown modules, or may include any combination of the shown modules and is not limited to the present example.

The user characterization adaptation module **62** retrieves logged data from the from the log data datastore **42**. In various embodiments, the logged data includes spoken commands **70** that were spoken by the user, and a performance **72** of the spoken commands **70**. The user characterization adaptation module **62** analyzes the commands **70** for various characteristics. The characteristics can include, for example, but are not limited to, verbosity, relational talk, information distribution, user demographics, tone of communication (e.g., politeness phrases), age, and gender. In various embodiments, the user characterization adaptation module **62** tracks how often the command **70** is associated with a particular characteristic. Once the command **70** has been associated with the particular characteristic with a certain frequency, the user characterization adaptation module **62** determines a language model **74** based on the characteristics of the command **70** or generates a new language model **74** by combining several language models (with or without weights) based on the characteristics.

In various embodiments, as shown in FIG. **4**, the user characterization adaptation module **62** includes one or more characteristic detector modules **100***a*-**100***n* and a language model selector and merger module **102**. Each characteristic detector module **100** analyzes the command **70** for one or more characteristics **105***a*-**105***n*. In various exemplary embodiments, the characteristic detector modules **100***a*-**100***n* output one or more characteristics **105***a*-**105***n* based on whether the particular command **70** is associated with particular characteristics and/or falls within a particular range of a particular characteristic(s). The language model selector and merger module **102** determines the language model **74** based on the detected characteristic(s) **105***a*-**105***n*. In various embodiments, the language model selector and merger module **102** determines the appropriate language model **74** from pre-stored models or a weighted combination of the models.

In various embodiments, the characteristic detector modules **100***a*-**100***n* can be a verbosity detector module, a politeness detector module, an information distribution detector module, a domain distribution detector module, a formality level detector module, an age detector module, a dialect detector module, and/or a gender detector module. The verbosity detector module, for example, analyzes the command **70** and estimates the percentage of decoration and non-functional words in the utterance and compares it to a known distribution of verbosity. The politeness detector module, for example, analyzes the command **70** and extracts all the politeness level indicator words. A weighted amount and relations among the different indicator words are then used to detect the level of politeness. The information distribution detector module, for example, analyzes the command **70** to detect a location and amount of required

information pieces (also known as the slot information). Based on this information, the information distribution detector module can detect a user that tends to provide the information as a single utterance and a user that does so piece by piece.

The domain distribution detector module, for example, analyzes the command **70** and detects a domain based on a comparison to historic behavior of the user. The formality level detector module, for example, analyzes the command **70** and extracts the vocabulary. The vocabulary of each level of formality is the basis of the space in which the detection takes place. The level can be determined by applying a normalized distance measure. The age detector module, for example, analyzes the command's utterance and uses a Gaussian Mixture Model (GMM) to compare the utterance to a reference model for each age or age group.

The dialect detector module, for example, analyzes the command **70** and extracts acoustic features. Using, for example, anchor models technique, a signature is generated and distances are measured. The gender detector module, for example, analyzes the command **70**, extracts acoustic features and estimates a GMM distribution for each gender. By transforming the GMM to Super Vector (SV) a distance is estimated and decision is made. As can be appreciated, other methods and techniques may be performed by each of the detector modules **100***a*-**100***n*. Thus, the disclosure is not limited to the present examples.

With reference back to FIG. **3**, the user competence adaptation module **64** retrieves logged data from the log data datastore **42**. In various embodiments, the logged data includes spoken commands **76** that are spoken by a user, and a performance **78** of the spoken commands **76**. The user competence adaptation module **64** analyzes the commands **76** based on the performance **78** of the commands **76**. In various embodiments, the performance **78** may generally include parameters and measurements for task completion success and for recurring errors of the user and/or system. For example, the parameters and measurements may pertain to, but are not limited to, task completion rate and time, time out events, response times, confirmation and disambiguation cycles, help requests, and all events, which deviate from an efficient and successful interaction sequence.

The user competence adaptation module **64** analyzes the commands **76** to identify patterns. The user competence adaptation module **64** provides suggested adjustments to prompts **80** and/or adjustments to interaction sequences **82** based on the identified patterns. The suggested adjustments may be provided as part of the user profile **56** (FIG. **2**). For example, the prompts **80** in the user profile **56** can be updated to contain more help and a narrower answer space after repeated errors by the user or system are identified; and the prompts **80** in the user profile **56** can be reverted back to original prompts after it is determined that the or system user learns optimal interaction behavior. In various embodiments, the interaction sequences **82** of the user profile **56** can be adapted to provide more system initiative for identified repeated user errors, and can be adapted to allow the user more initiative after it is determined that the user has learned the interaction pattern. This adapting of the user settings based on a user competence promotes improved user competence, and establishes an interaction pattern with a higher task completion rate.

For example, a user may be very familiar with speech systems in general using them frequently to enable applications via his mobile phone. Therefore he has a consistent way to express his request in a one-shot utterance, rarely having to add information later in a subsequent dialog. After the user competence adaptation module **64** gains the perspective and learns this pattern, it may decide to use minimal prompts to keep the dialog efficient and the task completion time short.

In another example, the same user may prefer to perform search requests, such as looking for a restaurant (e.g., a point of interest (POI search)). Based on his mobile phone experience he has developed the habit to go through a large search list and continue the interaction on the display, thoroughly looking into the options and choosing. He may be confused about how to choose by speech when the display will reduce the search content significantly due to the driving situation. After the user competence adaptation module **64** gains the perspective and learns this pattern, it may decide to guide the user step by step and with helpful prompts through this specific dialog situation, so that the user understands over time, how to search through the options.

In still another example, another user may be unfamiliar to speech. He understands the advantage during driving and starts to request by speech calling some of his contacts from his contact list or tuning the radio station. The user speaks overly slow and loud, thus the system has difficulties in recognizing most of the requests. This results in confirmation cycles for falsely recognized contacts or radio stations. The user becomes irritated and hesitates in his answers in these error recovery cycles. The user competence adaptation module **64** observes time out events, long response times, or verbose user utterances for confirmation cycles and guides the user through these situations by adding potential answers, helpful hints, or changing the prompt to strict yes/no answers.

In various exemplary embodiments, as shown in FIG. **5**, the user competence adaptation module **64** includes one or more pattern detector modules **104***a*-**104***n*, one or more setting calculator modules **106**, and one or more user profile adapter modules **108**. The one or more pattern detector modules **104***a*-**104***n* analyze the data to identify particular patterns **107***a*-**107***n*. The one or more setting calculator modules **106** determine settings **109** based on the detected patterns **107***a*-**107***n*. The one or more user profile adapter modules **108** provide the system prompts **80** and/or the interaction sequences **82** for the user profile **56** (FIG. **2**) based on the settings **109**.

The pattern detector modules **104***a*-**104***n* identify patterns **107***a*-**107***n* relating to, for example, task completion rate and time, time out events, user response times, user deviation from efficiently formulated utterances (e.g., hesitations, pauses, verbosity, etc.), low system confidence resulting in confirmation cycles, ambiguous user utterances resulting in disambiguation cycles, help requests, and all events which deviate from an efficient and successful interaction sequence. When the pattern detector module **104***a* identifies a pattern relating to task completion rate and time, the setting calculator module **106** generates settings **109** that change system prompts to more informative system prompts when the rate is below a certain threshold. In various embodiments, when the pattern detector module **104***a* identifies a pattern relating to time out events, user response times, or user deviation from efficiently formulated utterances, the setting calculator module **106** checks a relation to a current dialog step, if the dialog step is recurrently in the same step, the setting calculator module **106** generates settings **109** to change the prompt and the interaction sequence to smaller steps with close system questions for which the user knows easily how to give an answer (e.g., because the possible answer space is narrow).

When the pattern detector module **104***a* identifies a pattern relating to low system confidence resulting in confirmation cycles, the setting calculator module **106** generates settings **109** to change the prompts to more informative system prompts, so the user knows what to answer. When the pattern detector module **104***a* identifies a pattern relating to ambiguous user utterances resulting in disambiguation cycles, the setting calculator module **106** generates settings **109** to change the prompts to system prompts which tell the user how to include enough information in his answer to make it unambiguous. In various embodiments, when the pattern detector module **104***a* identifies a pattern relating to help requests, the setting calculator module **106** generates settings **109** to change the system prompts to more informative prompts. Such pattern detection can be done by collection of user data regarding recognition confusions of the system, detected, for example, by user rejected or corrected confirmation or disambiguation requests. In such a case, the data is stored in confusion matrices, which show recurring confusions over time.

For all identified patterns listed above, once the pattern detector modules **104***a*-**104***n* determine that the user's behavior has changed to be more efficient and/or easy to recognize, the setting calculator module **106** generates settings **109** to change the speech system prompts and/or interaction sequence back to an original setting, assuming that the user has gained expertise in the use of the system.

With reference back to FIG. **3**, the contextual data adaptation module **66** retrieves logged data from the from the log data datastore **42**. In various embodiments, the logged data includes vehicle data **84**, vehicle context data **86**, and speech system data **88**. The vehicle data **84** can include, but is not limited to, vehicle speed data, or any other data available on the communication bus **28**. The vehicle context data **86** can include, but is not limited to, a current driving location and time, a road type, traffic information, weather, an ambient noise level, a number of occupants, a number of connected user devices, any enabled Internet or other HMI applications, any enabled vehicle systems (i.e., climate control, active cruise control, lights, transmission gear, windshield wipers, etc.), or any other data available on the communication bus or directly from the vehicle systems **16**-**26**. The speech system data **88** can include, but is not limited to, the speech uttered by the user, the speech performance, and/or other speech characteristics identified by the speech system **10**.

The contextual data adaptation module **66** analyzes the logged data and detects recurring patterns between the context in which the user is using the system and the user's interaction behavior when using the speech system **10**. The contextual data adaptation module **66** provides updates to user task preferences **90**, natural language command preferences **92**, and/or interaction sequence preferences **94** based on the patterns. In various embodiments, the suggested adjustments are provided as part of the user profile **56** (FIG. **2**).

For example, traffic data provides information about a traffic jam at the route that the driver is driving. Additionally speed data from the CAN bus supports that the driver is in the traffic jam, and safety systems (seat belt settings) suggests that he is alone in the car. By evaluating the logged data, the pattern detector module **110***a* detects that the user makes a lot of phone calls or dictates emails, SMS, or updates his calendar at such times. The user profile **56** (FIG. **2**) is updated to recognize such times and to provide a recognition advantage to these types of requests during these conditions and performs with higher accuracy.

In another example, a driver is driving with other people on the weekend. An initial navigation request suggests a longer drive to a point of interest (POI), which is frequently visited by tourists. Additionally, the driver has connected his iPod and requests to listen to certain songs. By evaluating the logged data, the pattern detector module **110***a* detects that driver requests POIs and audio tours for POIs on the way and requests to listen to some of his favorite songs or audio tour of the POI from the iPod for such occasions. The user profile **56** (FIG. **2**) is updated to recognize such times and to provide a recognition advantage to these types of requests during these conditions and performs with higher accuracy.

In various exemplary embodiments, as shown in FIG. **6**, the contextual data adaptation module **66** can include one or more pattern detector modules **110***a*-**100***n*, one or more setting calculator modules **112**, and one or more user profile adapter modules **114**. The pattern detector modules **110***a*-**100***n* analyze the data for a particular pattern **115***a*-**115***n*. The pattern detector modules **110***a*-**110***n*, for example, detect contextual clusters in relation to user requests or request types. The setting calculator modules **112** determine user profile settings **117** based on the detected patterns **115***a*-**115***n*. The user profile adapter modules **114** provide user task preferences **90**, natural language command preferences **92**, and/or interaction sequence preferences **94** for use in the user profile **56** (FIG. **2**) based on the settings **117**.

In various embodiments, the pattern detector modules **110***a*-**110***n* determine the patterns by determining an increase in user behavior and by determining a pattern of context during the increase in user behavior. User behavior can be of various types and refer to the frequency of performing a certain task type, using a certain vocabulary/language, making recurring errors, or preferring a certain information distribution in his utterances (e.g. providing incremental information in more than one utterance versus saying all information to complete a task in one utterance, etc.). Once a pattern **115***a*-**115***n* is detected the setting calculator module **112** and the user profile adapter module **114** provide settings **117** and a user profile **56** (FIG. **2**) according to the recognized user behavior in the context, for example, according to a task preference, a vocabulary preference, a prompt preference, and/or an interaction sequence.

With reference back to FIG. **3**, the system model adaptation module **68** retrieves logged data from the from the log data datastore **42**. In various embodiments, the logged data includes a spoken command **96** that is spoken by the user. In various embodiments, the command **96** can be retrieved from the logged data in the log data datastore **42** (as shown), or alternatively can be received in real-time from the HMI module **14** (FIG. **1**) as the user speaks the command. The system model adaptation module **68** evaluates the command **96** and determines an optimal model for recognizing the command. For example, the system model adaptation module **68** evaluates the command according to at least three speech models and associates the command of the speech utterance with one of the three models. The system model adaptation module **68** tracks how often the command **96** is associated with the particular model. Once the command **96** has been associated with the particular model with a certain frequency, that model **98** is selected to be updated with the command **99** by adding the command **99** to the model or by removing the command **99** from the model. Additionally or alternatively, a weight or probability that matches an observed frequency of the command **99** or that matches an observed frequency of words, phrases, or transitions from

words to words within a command **99** may be associated with the command **99** and the model may be updated with the weight or probability.

Each model used offers an advantage in at least one of the following: the number of phrases supported, the depth of the phrases, a latency of the processing, the accuracy of the recognition, and the processing time. The combination of the models chosen provides advantages in at least two of the above listed. For example, in various embodiments, the first language model is a fixed model that includes a fixed list of recognizable commands, referred to as a fixed list model **116** (FIG. **10**). A fixed list model **116** offers the advantage of improved latency, improved accuracy, and improved processing time and can be considered a more optimal model. Such model can include, but is not limited to a Finite State Grammar (FSG). The second language model has a broader scope of recognition of phrases, referred to as a wider scope model **118** (FIG. **7**). A wider scope model **118** recognizes a wider scope of commands however provides higher latency and decreased accuracy. Such model can include, but is not limited to, a Statistical Language Model (SLM). The third language model is a combination between the two models such that it can arbitrate the results of the two language models, referred to as the arbitrator model **120** (FIG. **10**). Such model can include, but is not limited to, a Structural Equation Model (SEM). As can be appreciated, the models implemented by the system model adaptation module **68** can be any language models and are not limited to the present examples.

As can be appreciated, the data analyzer module **38** can include one adaptation module or any combination of the above described adaptation modules. In the case where multiple adaptation modules are implemented, the output of an adaptation module may be relied upon by other adaptation modules and or may be combined in some way by the system update module **40** (FIG. **2**). By tracking the commands in this manner, and migrating the commands from a less optimal model to a more optimal model, the more optimal model is taken advantage of without sacrificing flexibility of the system. Thus, recognition of the commands will improve over time with significantly less repetition requests or confirmation cycles.

Referring now to FIGS. **7-10** and with continued reference to FIGS. **1-6**, sequence diagrams illustrate adaptation methods that may be performed by the speech system **10** in accordance with various exemplary embodiments. As can be appreciated in light of the disclosure, the order of operation within the methods is not limited to the sequential execution as illustrated in FIGS. **7-10**, but may be performed in one or more varying orders as applicable and in accordance with the present disclosure. As can further be appreciated, one or more steps of the methods may be added or removed without altering the spirit of the method.

With reference to FIG. **7**, a sequence diagram illustrates an exemplary sequence that may be performed to adapt the speech system **10** based on user characterization. As shown, the commands, any contextual information, and their performance are received at **200** from, for example, the HMI module **14** (or communication bus **28**) and logged by the data logger module **36** at **202**. The logged data is retrieved from the log data datastore **42** at **210** and evaluated by the one or more characteristic detector modules **100***a*-**100***n* at **220**. The language model selector and merger module **102** then evaluates the identified characteristics **105***a*-**105***n* to see if the characteristic occurred with a certain frequency (e.g., X number of times, where X is a configurable number greater than one) and confidence at **230**. If the characteristic has occurred with a certain frequency, a language model **74** associated with the characteristic is selected and provided to the system update module **40** for updating at **240**. The system update module **40** receives the language model **74** at **250** and updates a current language model using the language model **74** (e.g., by combing the two models, or in some other manner) at **260**.

With reference to FIG. **8**, a sequence diagram illustrates an exemplary sequence that may be performed to adapt the speech system **10** based on user competence. As shown, the commands and performance data are received at **310**, for example, from the HMI module **14**, and logged by the data logger module **36** at **312**. The logged data is retrieved from the log data datastore **42** at **320**. The pattern detector modules **104***a*-**104***n* evaluate the logged data and compile recurring patterns **107***a*-**107***n* associated with user competence at **330**. The patterns **107***a*-**107***n* are sent to the settings calculator module **106** at **340**. Based on the patterns **107***a*-**107***n*, the settings calculator module **106** calculates recommended system interaction settings **109** for the overall interaction strategy (e.g. general verbosity level of prompts) and/or for specific dialogue situations (e.g. confirmation in specific context) at **350**. The user system interaction settings **109** are sent to the user profile adapter module **108** at **360**. The user profile adapter module **108** adapts the settings of the user profile at **370**. The user profile is sent to the system update module **40** at **380**. The system update module **40** updates the system settings with the adapted user profile at **390**.

With reference to FIG. **9**, a sequence diagram illustrates an exemplary sequence that may be performed to adapt the speech system **10** based on contextual data. As shown, the vehicle data **84**, the contextual data **86**, and the speech system data **88** are received at **410** and logged by the data logger module **36** at **412**. The logged data is retrieved from the log data datastore **42** at **420**. The pattern detector modules **110***a*-**110***n* evaluate the logged data and compiles recurring patterns **115***a*-**115***n* associated with data from other HMI module **14** (e.g. navigation system, cluster stack, Internet info) or logging systems of the vehicle (CAN bus), context data, such as current driving location and time, road type, traffic, weather, driving speed, ambient noise level, number of occupants, connected user devices, enabled Internet or other HMI applications, enabled vehicle systems, such as climate control, active cruise control, lights, transmission gear, windshield wipers, etc. at **430**.

The patterns **115***a*-**115***n* are sent to the settings calculator module **112** at **440**. Based on the patterns **115***a*-**115***n*, the settings calculator module **112** determines recommended system interaction settings **117** for the overall interaction strategy (e.g. general verbosity level of prompts) and/or for specific dialogue situations (e.g. confirmation in specific context at **450**. The user system interaction settings are sent to the user profile adapter module **114** at **460**. The user profile adapter module **114** adapts the settings of the user profile at **470**. The user profile is sent to the system update module **40** at **480**. The system update module **40** updates the system settings with the adapted user profile at **490**.

With reference to FIG. **10**, a sequence diagram illustrates an exemplary sequence that may be performed to adapt the speech system **10** based on adapted system models. As shown, the command is received at **510**, for example, from the HMI module **14**, and logged by the data logger module **36** at **512**. The command is retrieved from the log data datastore **42** at **520**. Alternatively, the command **96** is directly received from the HMI module **14** at **530**. The command **96** is processed by the system model adaptation

module **68** to determine the optimal language model for the command. For example, the command **96** is processed by the fixed list model **116** at **540** and sent to the arbitrator model **120** at **550**. The command **96** is simultaneously or shortly thereafter, retrieved from the log data datastore **42** at **555** and processed by the wider scope model **118** at **560**. Alternatively, the command **96** is directly received from the HMI module **14** at **557** and processed by the wider scope model **118** at **560**.

The results of the wider scope model **118** are sent to arbitrator model **120** at **570**. The results of the fixed list model **116** and the wider scope model **118** are processed by the arbitrator model **120** at **580**. The results of the arbitrator are evaluated to see if the result has occurred with a certain frequency (e.g., X number of times, where X is a configurable number greater than one) at **590**. If the result of the arbitrator has occurred with a certain frequency, the result and the model are provided to the system update module **40** for updating at **600**. The system update module receives the result and the model and updates the system model with the result at **610**.

While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment or exemplary embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the disclosure as set forth in the appended claims and the legal equivalents thereof.

What is claimed is:

1. A method of adapting a speech system, comprising:

logging speech data from the speech system;

processing the speech data, by a plurality of characteristic detector modules, to detect a plurality of user characteristics from the speech data, the plurality of characteristic detector modules each map the speech data into at least one category associated with at least one user characteristic of the plurality of user characteristics, the user characteristics comprise characteristics that are specific to behavior of a user of a vehicle when saying a command to an automated system;

tracking a frequency of each of the plurality of user characteristics; and

when the frequency of at least one of the plurality of user characteristics reaches a certain frequency, selecting a language model associated with the user of the vehicle, and updating the language model based on the categories of the plurality of the user characteristics.

2. The method of claim **1** wherein the speech data comprises a spoken command uttered by a user when interacting with the speech system and a performance of the spoken command.

3. The method of claim **1** wherein the updating the language model comprises generating a new language model based on the plurality of user characteristics.

4. The method of claim **1** wherein the updating the language model comprises combining a plurality of language models associated with the plurality of user characteristics with at least one other language model.

5. The method of claim **1** wherein the user characteristics comprise at least one of a verbosity detected by a percentage of decoration or non-functional words, an information distribution detected by a delivery method of information, and a domain distribution detected by a domain historic behavior.

6. The method of claim **1** wherein the user characteristics comprise at least one of a politeness, and a formality level.

7. The method of claim **1** wherein the user characteristics comprise at least one of an age, a dialect, and a gender.

8. A system for adapting a speech system, comprising:

a computer readable medium comprising:

a first module that, by a processor, logs speech data from the speech system;

a second module that, by a processor, processes the speech data to detect by a plurality of characteristic detector modules a plurality of user characteristics from the speech data, the plurality of characteristic detector modules each map the speech data into at least one category associated with at least one user characteristic of the plurality of user characteristics, and track a frequency of each of the plurality of user characteristics, the user characteristics comprise characteristics that are specific to behavior of a user of a vehicle when saying a command to an automated system; and

a third module that, by a processor, when the frequency of at least one of the plurality of user characteristics reaches a certain frequency, selects a language model associated with the user of the vehicle, and updates the language model based on the categories of the plurality of the user characteristics.

9. The system of claim **8** wherein the speech data comprises a spoken command uttered by a user when interacting with the speech system and a performance of the spoken command.

10. The system of claim **8** wherein the third module updates the language model by generating a new language model based on the plurality of user characteristics.

11. The system of claim **8** wherein the third module updates the language model by combining a plurality of language models associated with the plurality of user characteristics with at least one other language model.

12. The system of claim **8** wherein the plurality of user characteristics comprise at least one of a verbosity, an information distribution, and a domain distribution.

13. The system of claim **8** wherein the plurality of user characteristics comprise at least one of a politeness, and a formality level.

14. The system of claim **8** wherein the plurality of user characteristics comprise at least one of an age, a dialect, and a gender.

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