US007177807B1

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Schmid et al.

(10) **Patent No.: US 7,177,807 B1**
(45) **Date of Patent: Feb. 13, 2007**

(54) **MIDDLEWARE LAYER BETWEEN SPEECH RELATED APPLICATIONS AND ENGINES**

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(73) Assignee: **Microsoft Corporation**, Redmond, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/006,236**

(22) Filed: **Dec. 6, 2004**

Related U.S. Application Data

(62) Division of application No. 09/751,836, filed on Dec. 29, 2000.

(60) Provisional application No. 60/219,861, filed on Jul. 20, 2000, now abandoned.

(51) **Int. Cl.**
G10L 15/00 (2006.01)
G10L 13/00 (2006.01)

(52) **U.S. Cl.** **704/231**; 704/258; 704/270

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

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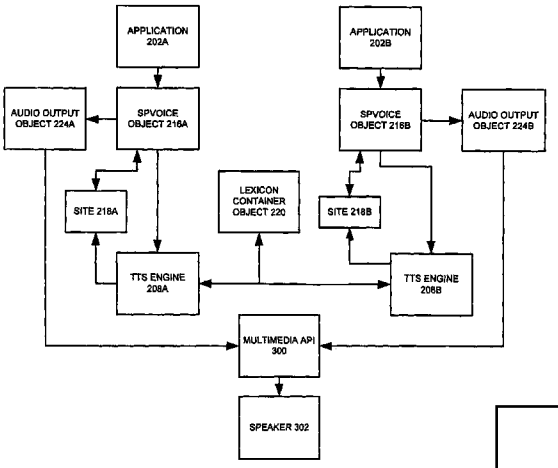
Assistant Examiner—Matthew J Sked
(74) *Attorney, Agent, or Firm*—Westman, Champlin & Kelly, P.A.

(57) **ABSTRACT**

The present invention provides an application-independent and engine-independent middleware layer (**204**) between applications (**202**) and engines (**206**, **208**). The middleware provides speech-related services to both applications (**202**) and engines (**206**, **208**), thereby making it far easier for application vendors and engine vendors to bring their technology to consumers.

9 Claims, 14 Drawing Sheets



Samsung v. Cerence
IPR2025-00459
Exhibit 1010

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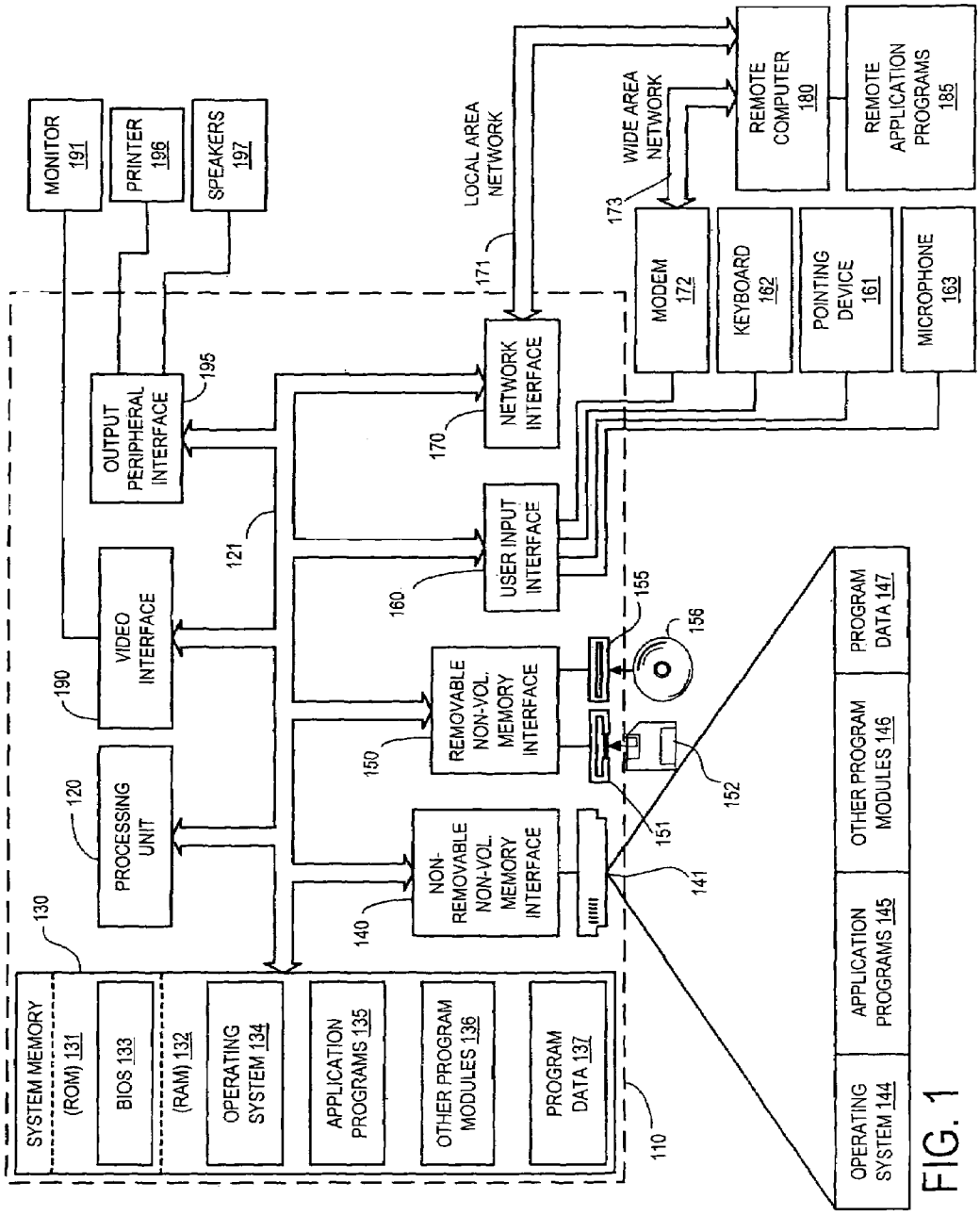

MONITOR 191
PRINTER 196
SPEAKERS 197
LOCAL AREA NETWORK
WIDE AREA NETWORK
REMOTE COMPUTER 180
REMOTE APPLICATION PROGRAMS 185
173
171
MODEM 172
KEYBOARD 162
POINTING DEVICE 161
MICROPHONE 163
OUTPUT PERIPHERAL INTERFACE
195
NETWORK INTERFACE
170
121
USER INPUT INTERFACE
160
VIDEO INTERFACE
190
155
156
REMOVABLE NON-VOL. MEMORY INTERFACE
150
PROCESSING UNIT
120
152
151
NON-REMOVABLE NON-VOL. MEMORY INTERFACE
141
140
130
SYSTEM MEMORY
(ROM) 131
BIOS 133
(RAM) 132
OPERATING SYSTEM 134
APPLICATION PROGRAMS 135
OTHER PROGRAM MODULES 136
PROGRAM DATA 137
110
PROGRAM DATA 147
OTHER PROGRAM MODULES 146
APPLICATION PROGRAMS 145
OPERATING SYSTEM 144

FIG. 1

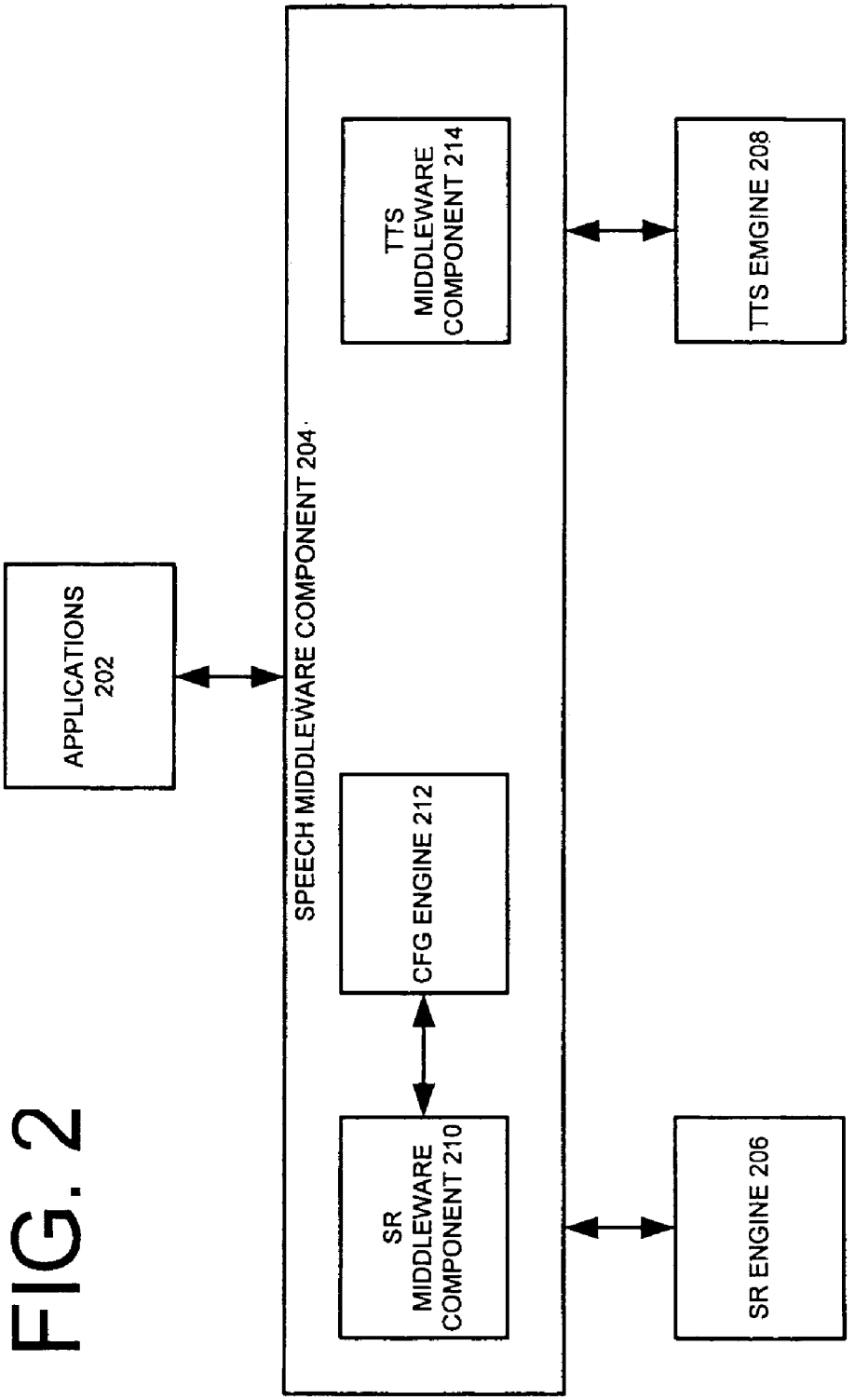

APPLICATIONS
202
SPEECH MIDDLEWARE COMPONENT 204
SR
MIDDLEWARE
COMPONENT 210
CFG ENGINE 212
TTS
MIDDLEWARE
COMPONENT 214
SR ENGINE 206
TTS EMGINE 208

FIG. 2

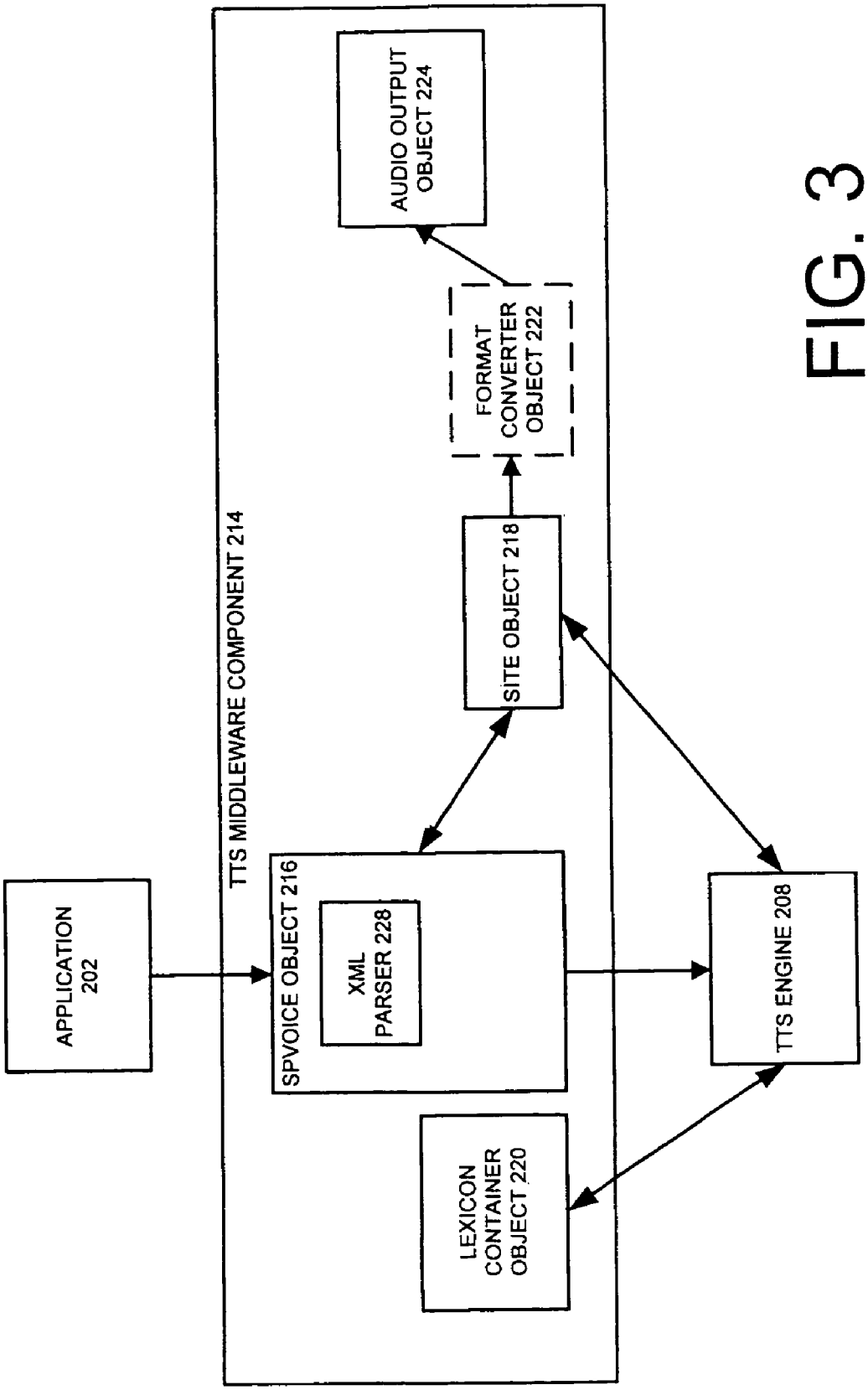

APPLICATION 202
TTS MIDDLEWARE COMPONENT 214
SPVOICE OBJECT 216
XML PARSER 228
SITE OBJECT 218
FORMAT CONVERTER OBJECT 222
AUDIO OUTPUT OBJECT 224
LEXICON CONTAINER OBJECT 220
TTS ENGINE 208

FIG. 3

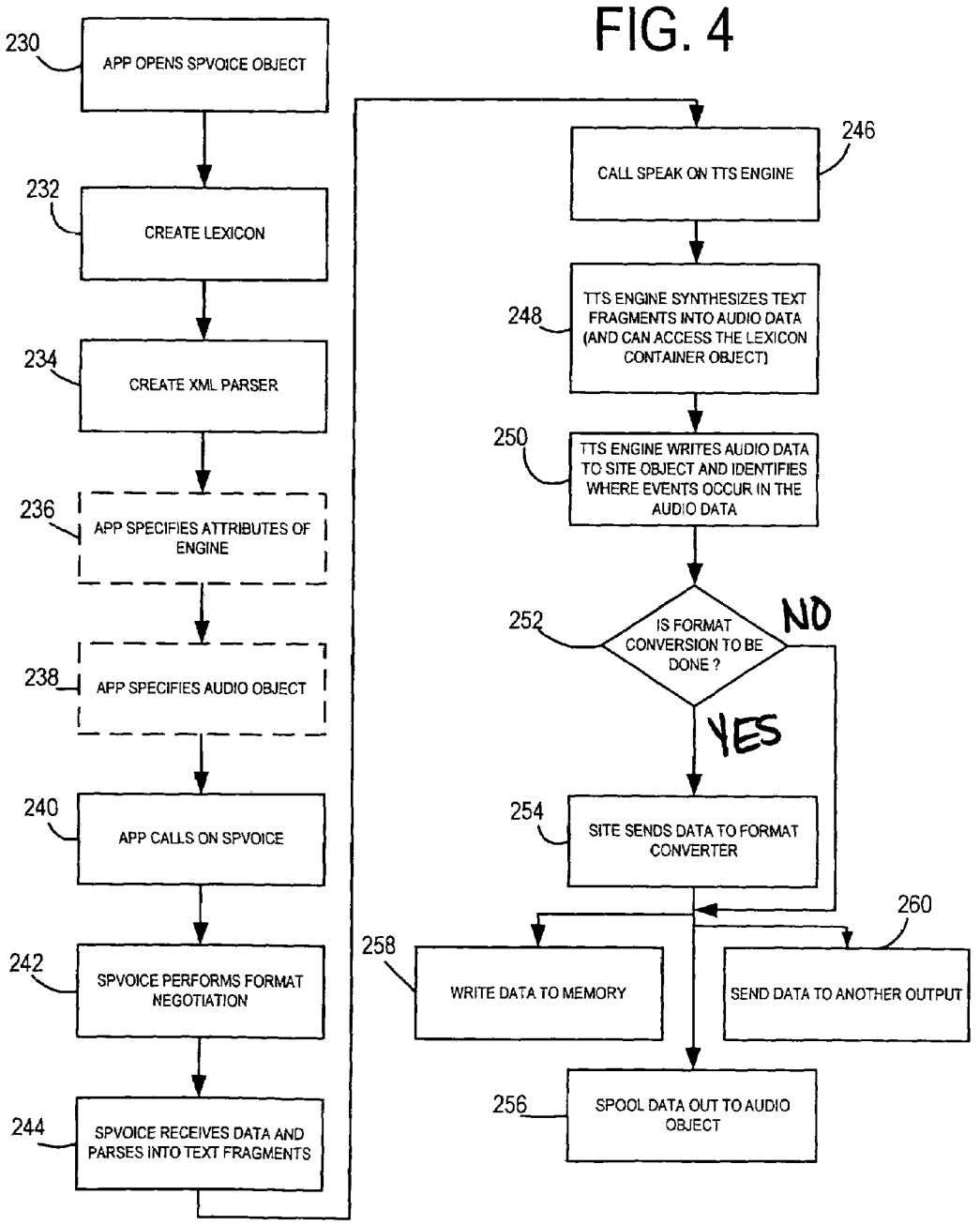


FIG. 4
230
APP OPENS SPVOICE OBJECT
232
CREATE LEXICON
234
CREATE XML PARSER
236
APP SPECIFIES ATTRIBUTES OF ENGINE
238
APP SPECIFIES AUDIO OBJECT
240
APP CALLS ON SPVOICE
242
SPVOICE PERFORMS FORMAT NEGOTIATION
244
SPVOICE RECEIVES DATA AND PARSES INTO TEXT FRAGMENTS
246
CALL SPEAK ON TTS ENGINE
248
TTS ENGINE SYNTHESIZES TEXT FRAGMENTS INTO AUDIO DATA (AND CAN ACCESS THE LEXICON CONTAINER OBJECT)
250
TTS ENGINE WRITES AUDIO DATA TO SITE OBJECT AND IDENTIFIES WHERE EVENTS OCCUR IN THE AUDIO DATA
252
IS FORMAT CONVERSION TO BE DONE ?
NO
YES
254
SITE SENDS DATA TO FORMAT CONVERTER
258
WRITE DATA TO MEMORY
260
SEND DATA TO ANOTHER OUTPUT
256
SPOOL DATA OUT TO AUDIO OBJECT

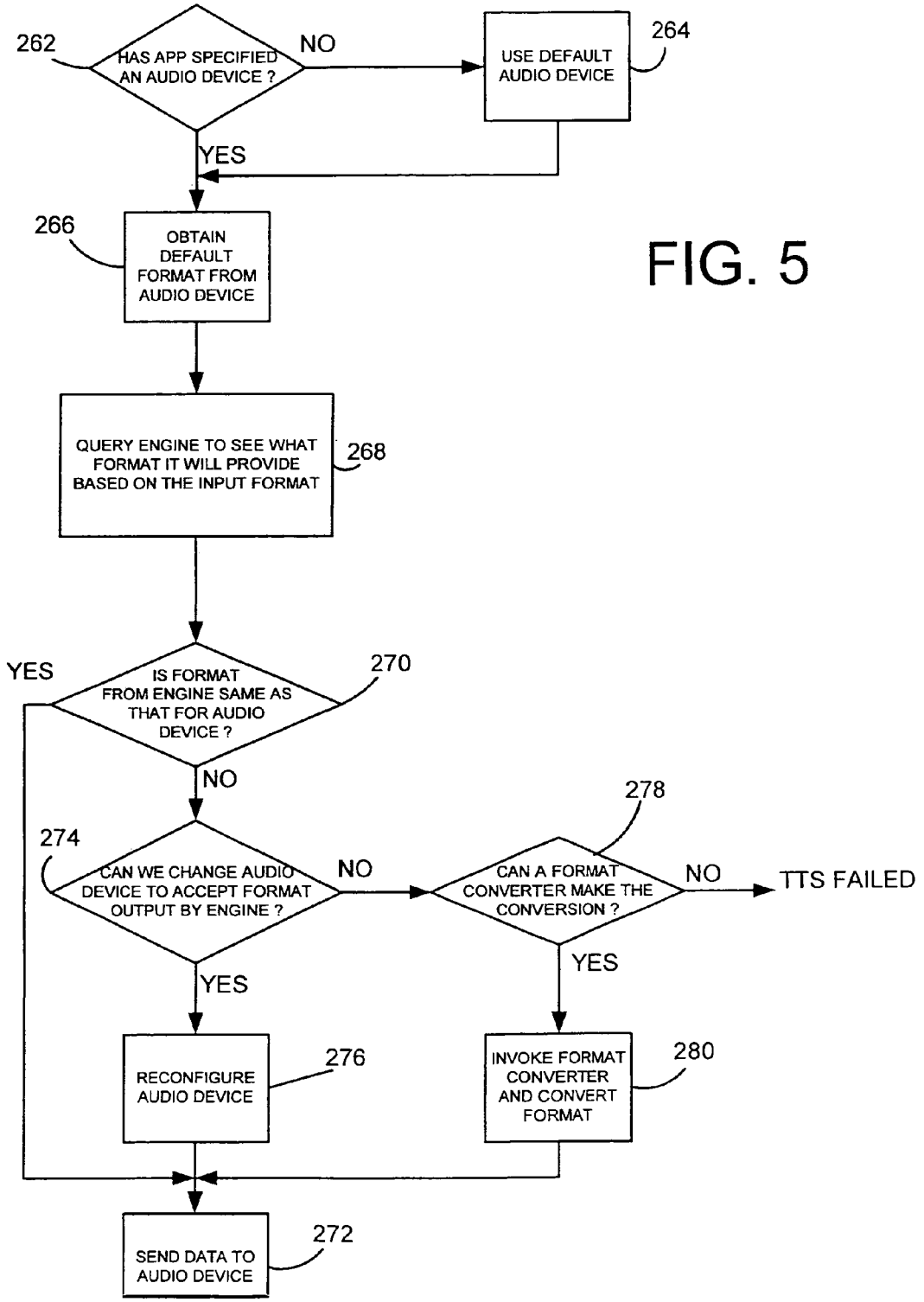

262
HAS APP SPECIFIED AN AUDIO DEVICE ?
NO
USE DEFAULT AUDIO DEVICE
264
YES
266
OBTAIN DEFAULT FORMAT FROM AUDIO DEVICE
QUERY ENGINE TO SEE WHAT FORMAT IT WILL PROVIDE BASED ON THE INPUT FORMAT
268
YES
IS FORMAT FROM ENGINE SAME AS THAT FOR AUDIO DEVICE ?
270
NO
274
CAN WE CHANGE AUDIO DEVICE TO ACCEPT FORMAT OUTPUT BY ENGINE ?
NO
278
CAN A FORMAT CONVERTER MAKE THE CONVERSION ?
NO
TTS FAILED
YES
YES
RECONFIGURE AUDIO DEVICE
276
INVOKE FORMAT CONVERTER AND CONVERT FORMAT
280
SEND DATA TO AUDIO DEVICE
272

FIG. 5

FIG. 6

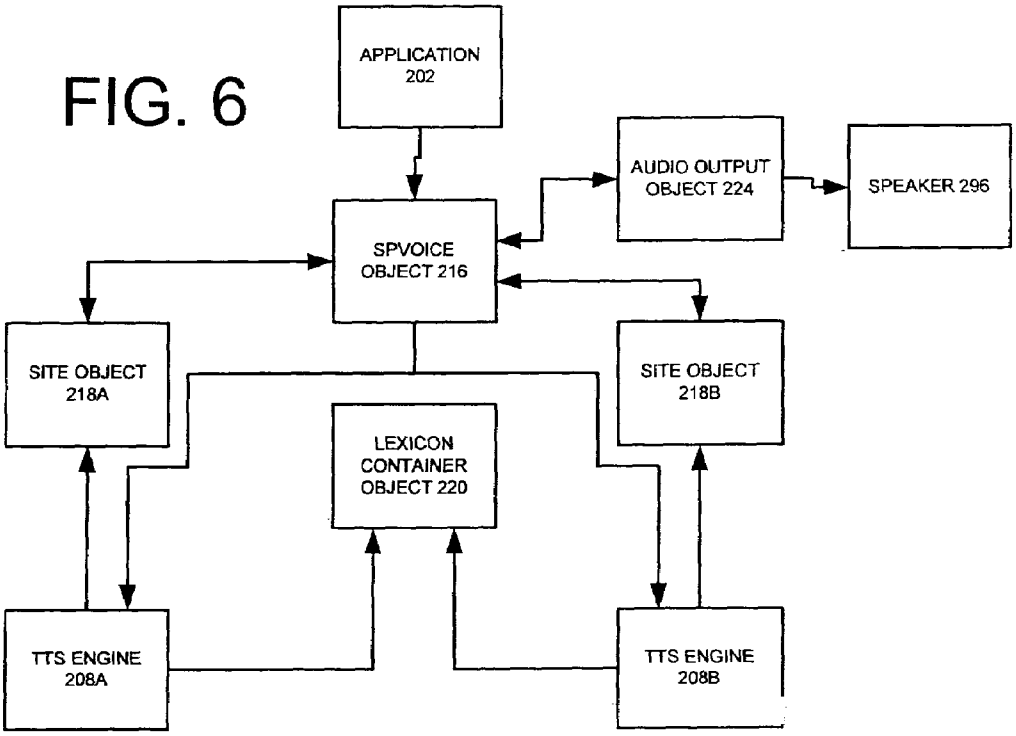
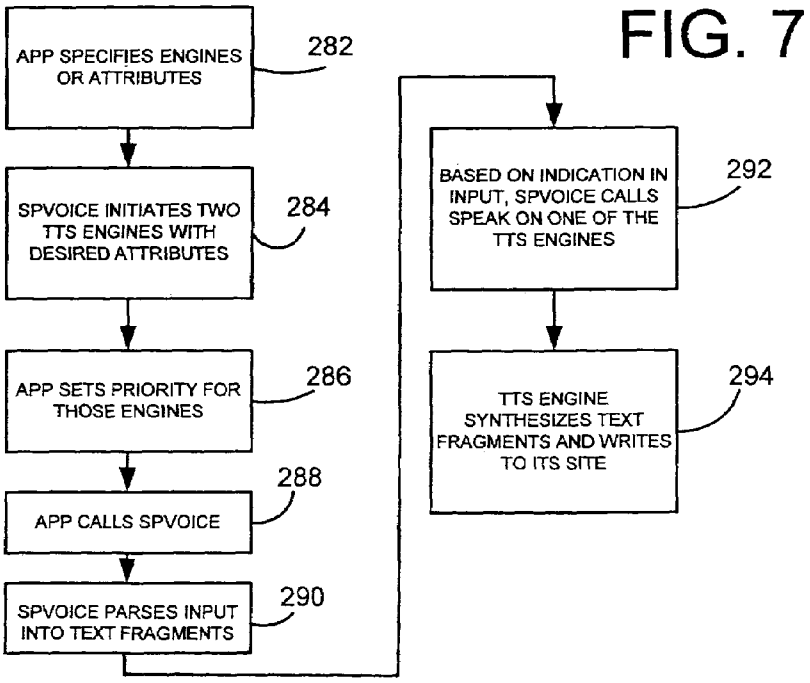

APPLICATION 202
AUDIO OUTPUT OBJECT 224
SPEAKER 296
SPVOICE OBJECT 216
SITE OBJECT 218A
SITE OBJECT 218B
LEXICON CONTAINER OBJECT 220
TTS ENGINE 208A
TTS ENGINE 208B

FIG. 7


APP SPECIFIES ENGINES OR ATTRIBUTES
282
SPVOICE INITIATES TWO TTS ENGINES WITH DESIRED ATTRIBUTES
284
APP SETS PRIORITY FOR THOSE ENGINES
286
APP CALLS SPVOICE
288
SPVOICE PARSES INPUT INTO TEXT FRAGMENTS
290
BASED ON INDICATION IN INPUT, SPVOICE CALLS SPEAK ON ONE OF THE TTS ENGINES
292
TTS ENGINE SYNTHESIZES TEXT FRAGMENTS AND WRITES TO ITS SITE
294

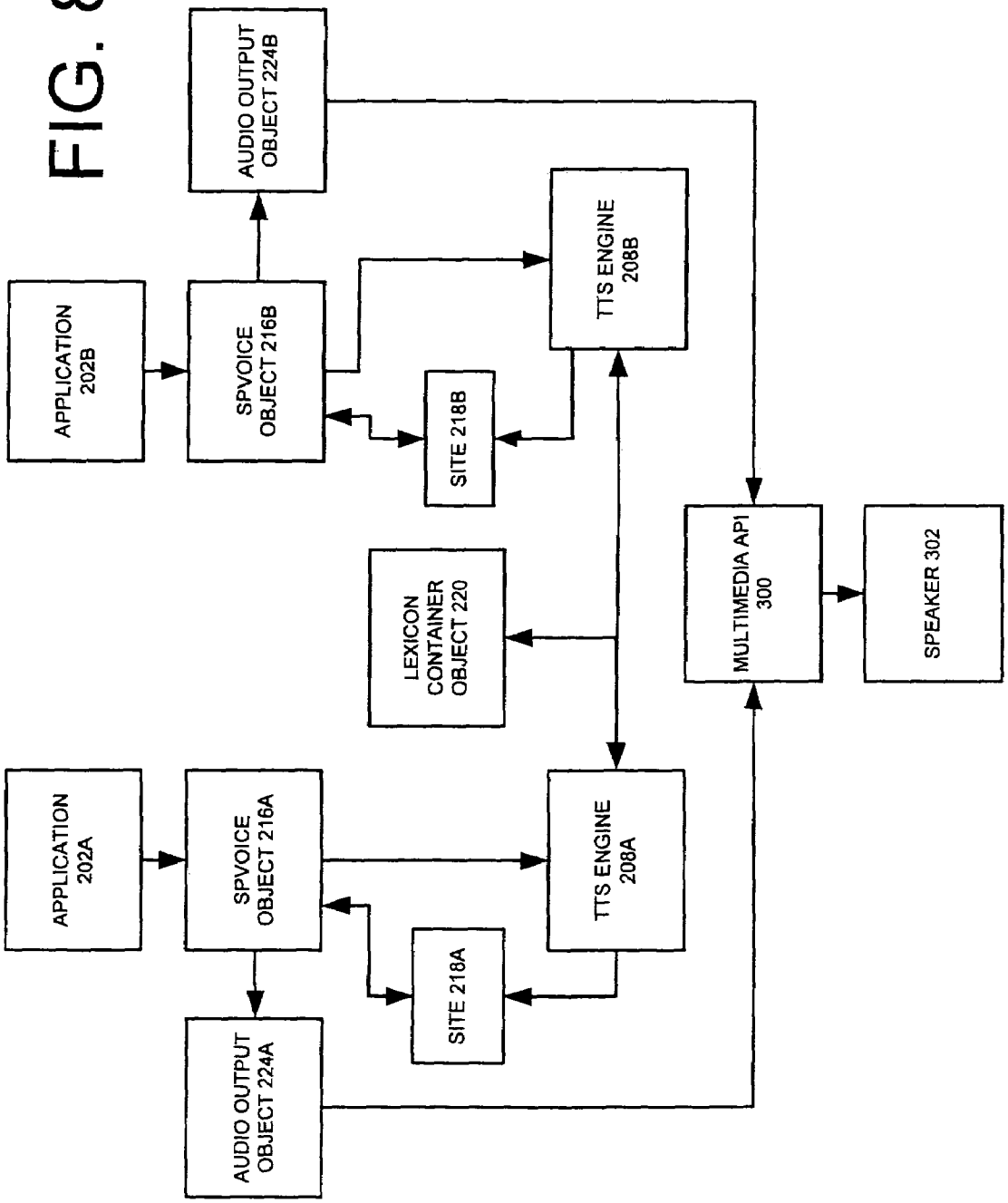

APPLICATION 202B
SPVOICE OBJECT 216B
AUDIO OUTPUT OBJECT 224B
SITE 218B
TTS ENGINE 208B
LEXICON CONTAINER OBJECT 220
MULTIMEDIA API 300
SPEAKER 302
APPLICATION 202A
SPVOICE OBJECT 216A
SITE 218A
TTS ENGINE 208A
AUDIO OUTPUT OBJECT 224A

FIG. 8

FIG. 9

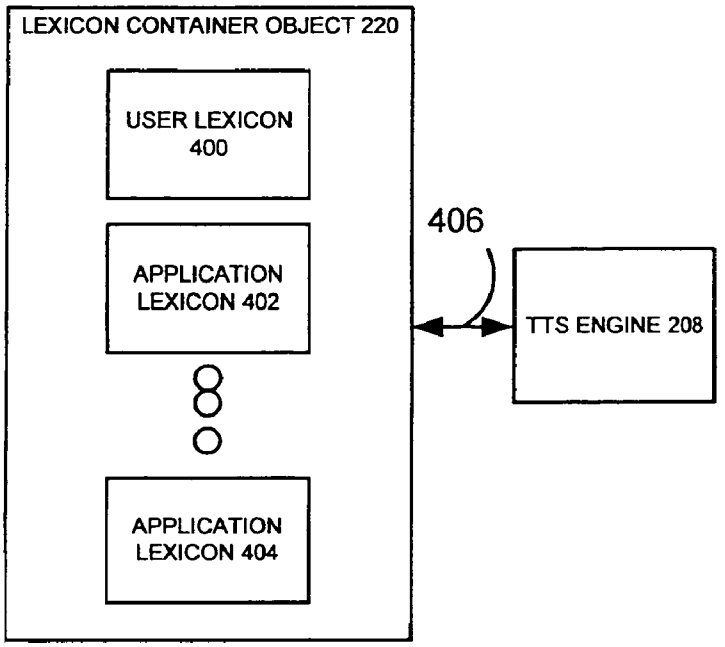
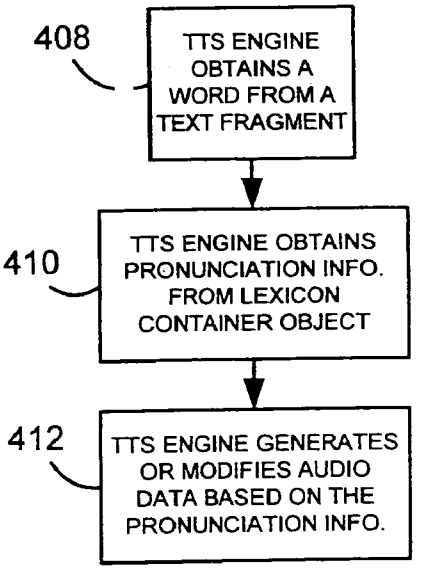

LEXICON CONTAINER OBJECT 220
USER LEXICON 400
APPLICATION LEXICON 402
APPLICATION LEXICON 404
406
TTS ENGINE 208

FIG. 10


408
TTS ENGINE OBTAINS A WORD FROM A TEXT FRAGMENT
410
TTS ENGINE OBTAINS PRONUNCIATION INFO. FROM LEXICON CONTAINER OBJECT
412
TTS ENGINE GENERATES OR MODIFIES AUDIO DATA BASED ON THE PRONUNCIATION INFO.

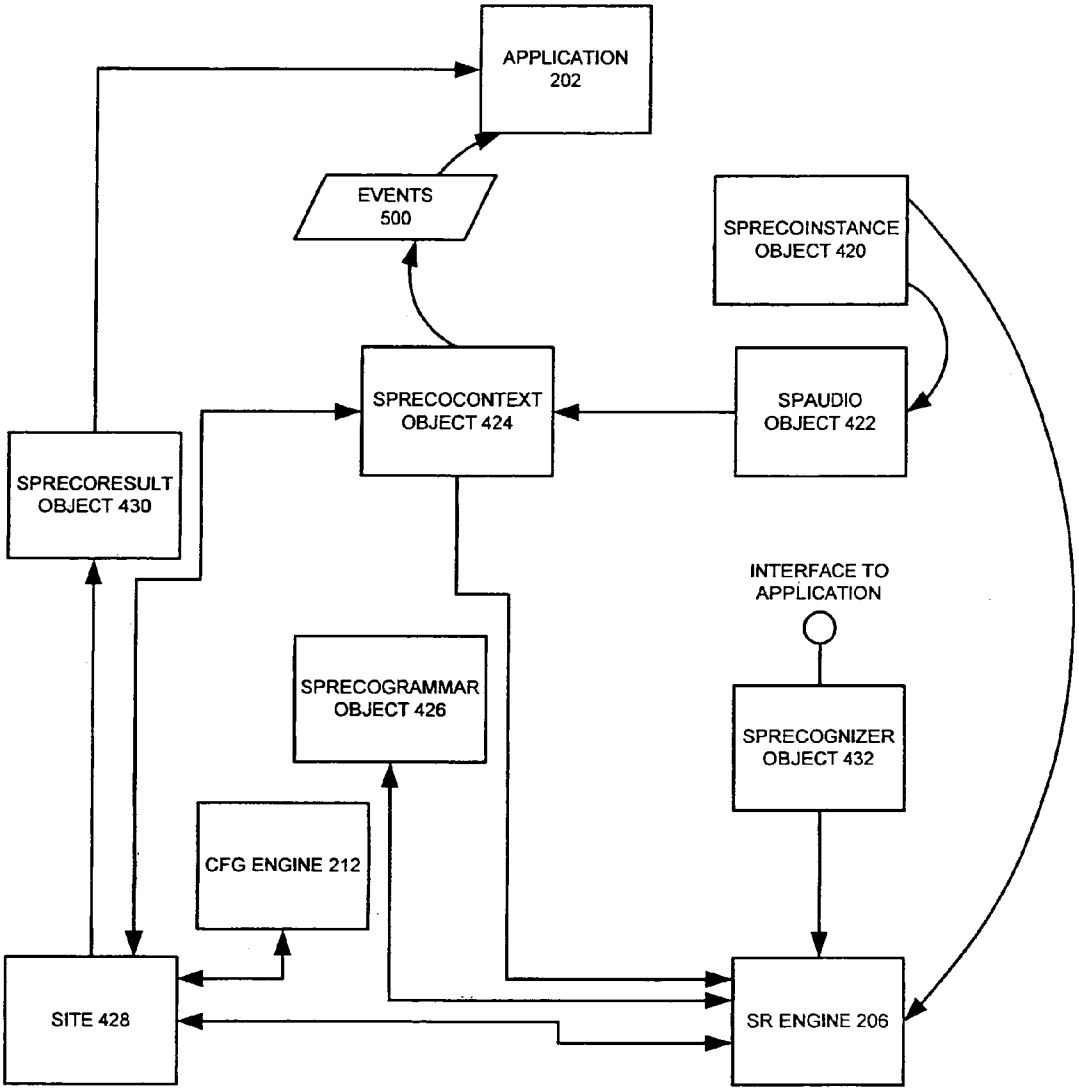

APPLICATION
202
EVENTS
500
SPRECOINSTANCE
OBJECT 420
SPRECOCONTEXT
OBJECT 424
SPAUDIO
OBJECT 422
SPRECORESULT
OBJECT 430
INTERFACE TO
APPLICATION
SPRECOGRAMMAR
OBJECT 426
SPRECOGNIZER
OBJECT 432
CFG ENGINE 212
SITE 428
SR ENGINE 206

FIG. 11

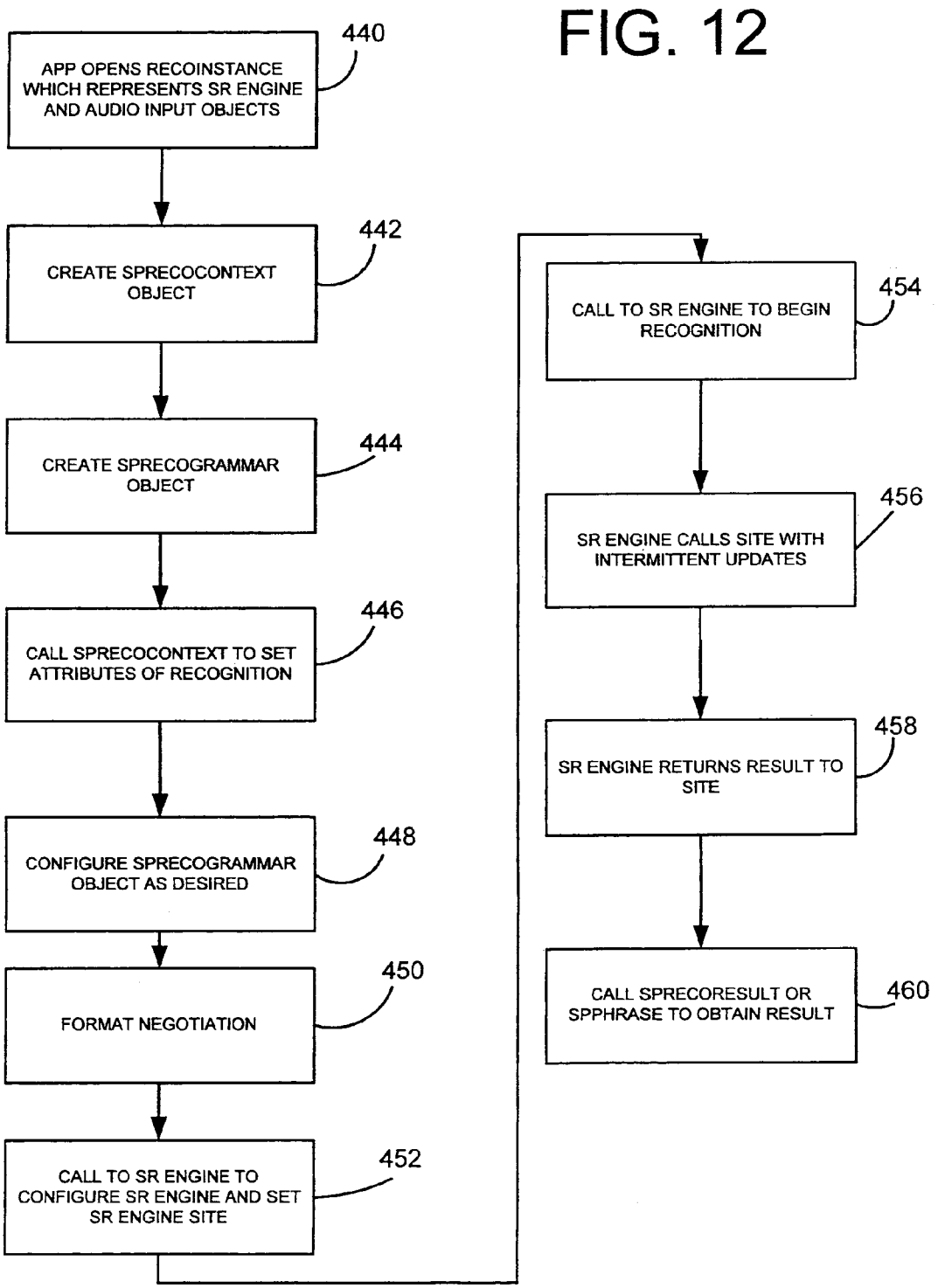


FIG. 12
APP OPENS RECOINSTANCE WHICH REPRESENTS SR ENGINE AND AUDIO INPUT OBJECTS
440
CREATE SPRECOCONTEXT OBJECT
442
CREATE SPRECOGRAMMAR OBJECT
444
CALL SPRECOCONTEXT TO SET ATTRIBUTES OF RECOGNITION
446
CONFIGURE SPRECOGRAMMAR OBJECT AS DESIRED
448
FORMAT NEGOTIATION
450
CALL TO SR ENGINE TO CONFIGURE SR ENGINE AND SET SR ENGINE SITE
452
CALL TO SR ENGINE TO BEGIN RECOGNITION
454
SR ENGINE CALLS SITE WITH INTERMITTENT UPDATES
456
SR ENGINE RETURNS RESULT TO SITE
458
CALL SPRECORESULT OR SPPHRASE TO OBTAIN RESULT
460

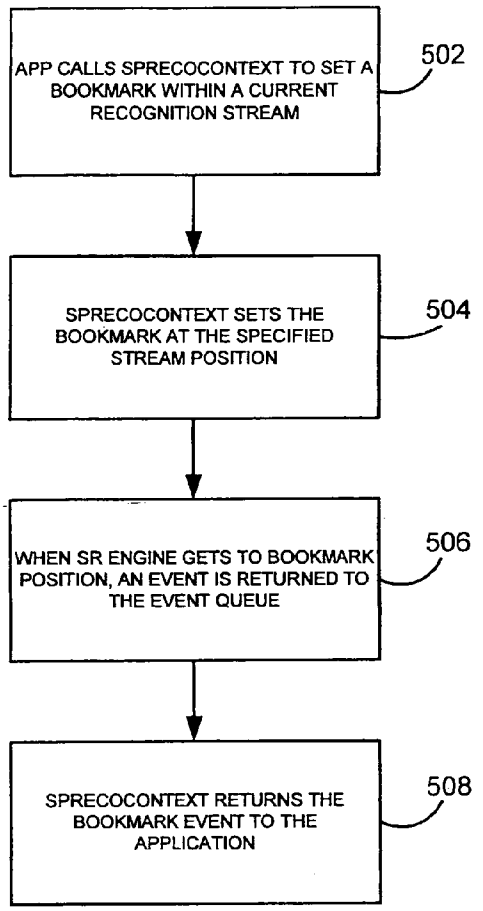

APP CALLS SPRECOCONTEXT TO SET A BOOKMARK WITHIN A CURRENT RECOGNITION STREAM
502
SPRECOCONTEXT SETS THE BOOKMARK AT THE SPECIFIED STREAM POSITION
504
WHEN SR ENGINE GETS TO BOOKMARK POSITION, AN EVENT IS RETURNED TO THE EVENT QUEUE
506
SPRECOCONTEXT RETURNS THE BOOKMARK EVENT TO THE APPLICATION
508

FIG. 13

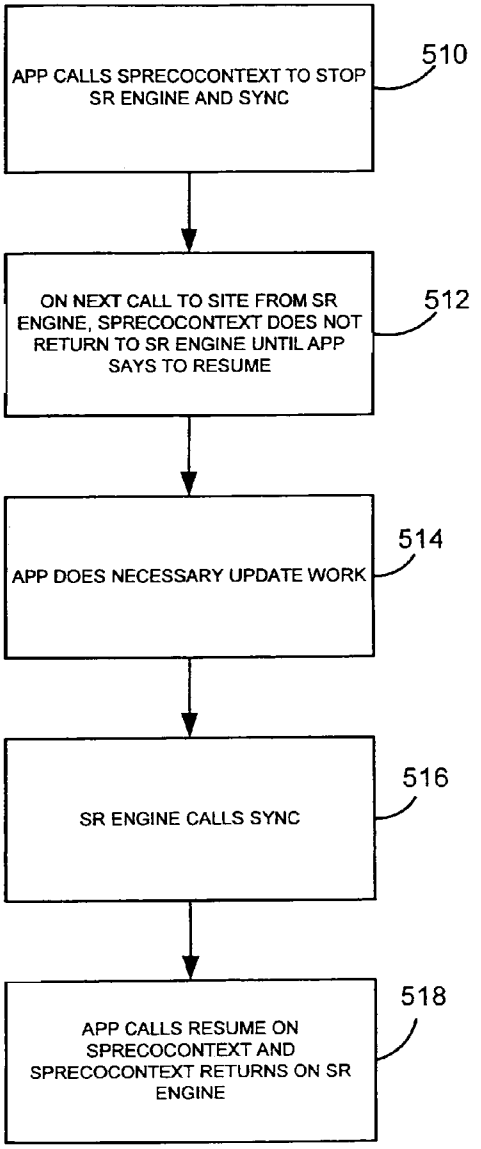
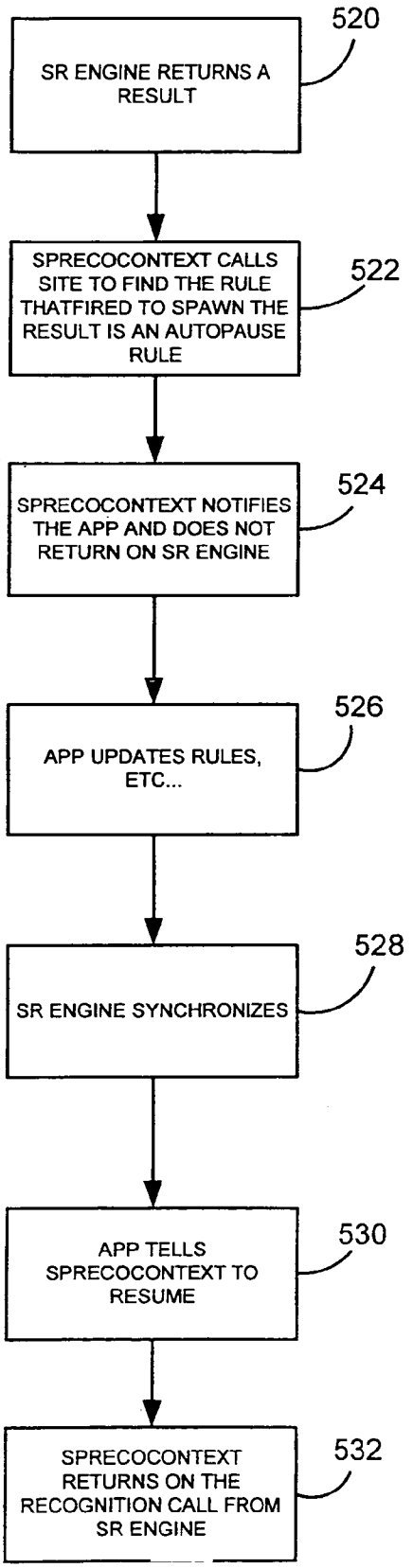

APP CALLS SPRECOCONTEXT TO STOP SR ENGINE AND SYNC
510
ON NEXT CALL TO SITE FROM SR ENGINE, SPRECOCONTEXT DOES NOT RETURN TO SR ENGINE UNTIL APP SAYS TO RESUME
512
APP DOES NECESSARY UPDATE WORK
514
SR ENGINE CALLS SYNC
516
APP CALLS RESUME ON SPRECOCONTEXT AND SPRECOCONTEXT RETURNS ON SR ENGINE
518

FIG. 14

FIG. 15


520
SR ENGINE RETURNS A RESULT
522
SPRECOCONTEXT CALLS SITE TO FIND THE RULE THATFIRED TO SPAWN THE RESULT IS AN AUTOPAUSE RULE
524
SPRECOCONTEXT NOTIFIES THE APP AND DOES NOT RETURN ON SR ENGINE
526
APP UPDATES RULES, ETC...
528
SR ENGINE SYNCHRONIZES
530
APP TELLS SPRECOCONTEXT TO RESUME
532
SPRECOCONTEXT RETURNS ON THE RECOGNITION CALL FROM SR ENGINE

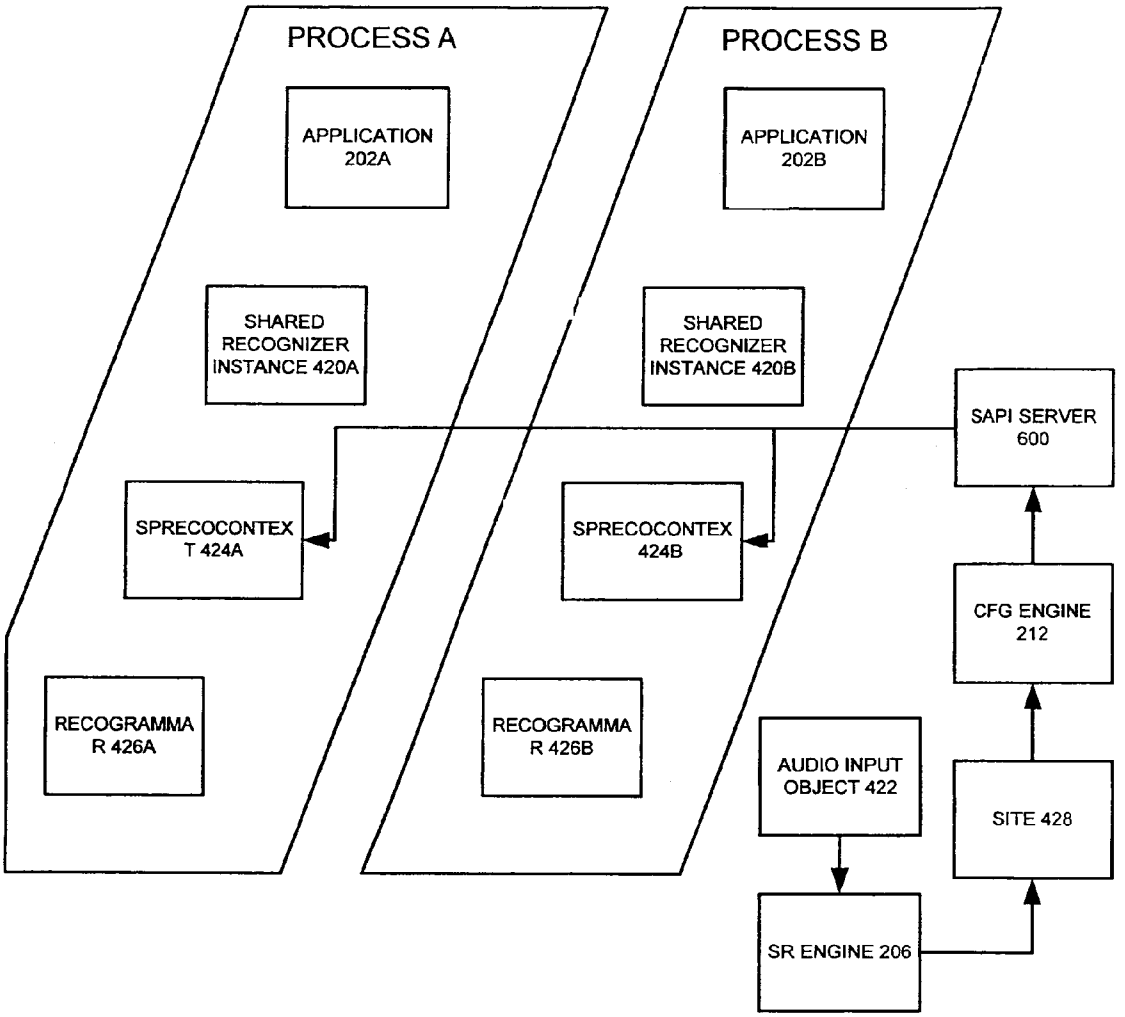

PROCESS A
APPLICATION 202A
SHARED RECOGNIZER INSTANCE 420A
SPRECOCONTEX T 424A
RECOGRAMMA R 426A
PROCESS B
APPLICATION 202B
SHARED RECOGNIZER INSTANCE 420B
SPRECOCONTEX 424B
RECOGRAMMA R 426B
SAPI SERVER 600
CFG ENGINE 212
SITE 428
AUDIO INPUT OBJECT 422
SR ENGINE 206

FIG. 16

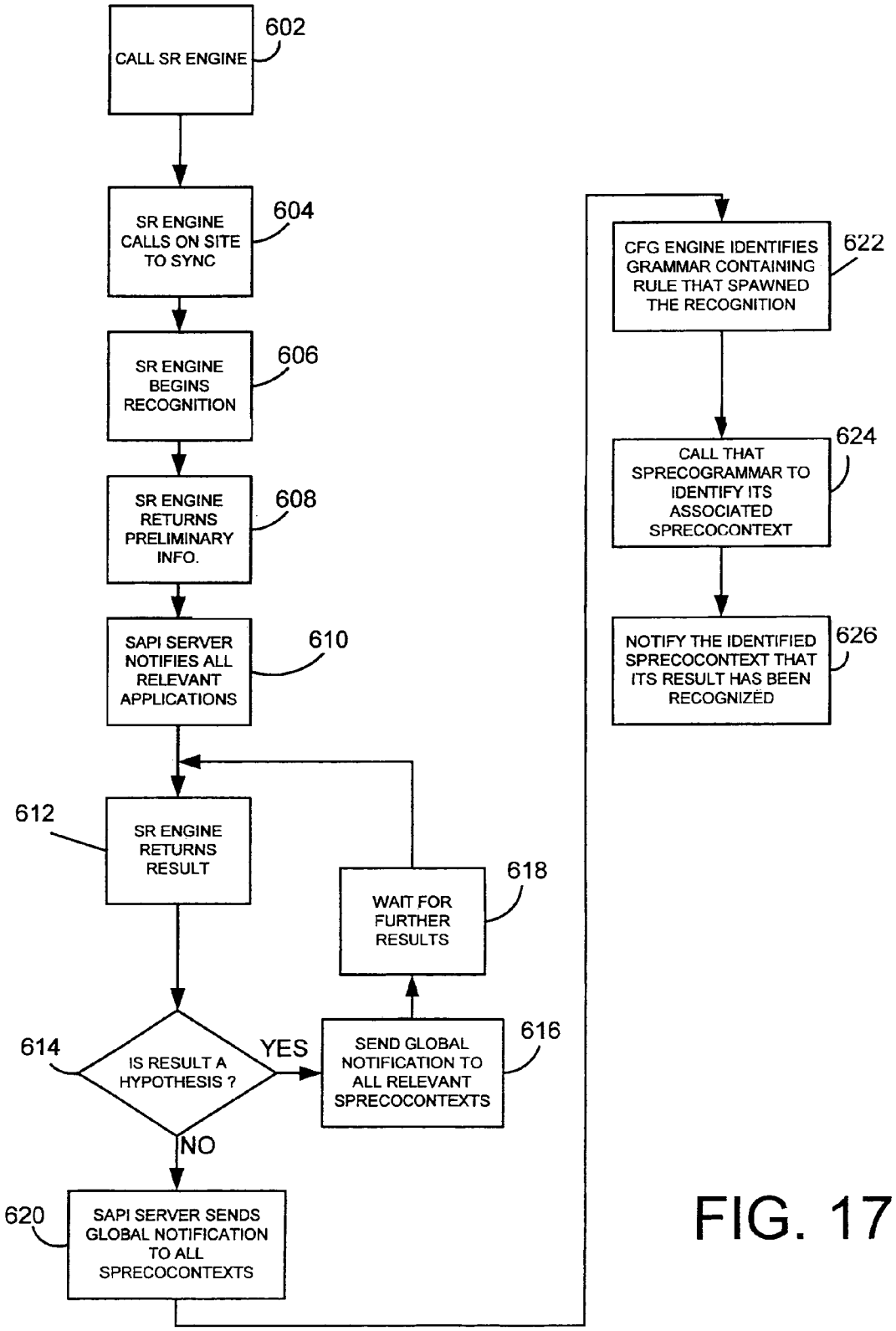

CALL SR ENGINE
602
SR ENGINE CALLS ON SITE TO SYNC
604
SR ENGINE BEGINS RECOGNITION
606
SR ENGINE RETURNS PRELIMINARY INFO.
608
SAPI SERVER NOTIFIES ALL RELEVANT APPLICATIONS
610
612
SR ENGINE RETURNS RESULT
WAIT FOR FURTHER RESULTS
618
614
IS RESULT A HYPOTHESIS ?
YES
SEND GLOBAL NOTIFICATION TO ALL RELEVANT SPRECOCONTEXTS
616
NO
620
SAPI SERVER SENDS GLOBAL NOTIFICATION TO ALL SPRECOCONTEXTS
CFG ENGINE IDENTIFIES GRAMMAR CONTAINING RULE THAT SPAWNED THE RECOGNITION
622
CALL THAT SPRECOGRAMMAR TO IDENTIFY ITS ASSOCIATED SPRECOCONTEXT
624
NOTIFY THE IDENTIFIED SPRECOCONTEXT THAT ITS RESULT HAS BEEN RECOGNIZED
626

FIG. 17

MIDDLEWARE LAYER BETWEEN SPEECH RELATED APPLICATIONS AND ENGINES

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of and claims priority of U.S. patent application Ser. No. 09/751,836, filed Dec. 29, 2000, and is related to co-pending application Ser. No. 11/012,547, filed Dec. 15, 2004, the contents of which are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

The present invention deals with services for enabling speech recognition and speech synthesis technology. In particular, the present invention relates to a middleware layer which resides between applications and engines (i.e., speech recognizers and speech synthesizers) and provides services, on an application-independent and engine-independent basis, for both applications and engines.

Speech synthesis engines typically include a decoder which receives textual information and converts it to audio information which can be synthesized into speech on an audio device. Speech recognition engines typically include a decoder which receives audio information in the form of a speech signal and identifies a sequence of words from the speech signal.

In the past, applications which invoked these engines communicated directly with the engines. Because the engines from each vendor interacted with applications directly, the behavior of that interaction was unpredictable and inconsistent. This made it virtually impossible to change synthesis or recognition engines without inducing errors in the application. It is believed that, because of these difficulties, speech recognition technology and speech synthesis technology have not quickly gained wide acceptance.

In an effort to make such technology more readily available, an interface between engines and applications was specified by a set of application programming interfaces (API's) referred to as the Microsoft Speech API version 4.0 (SAPI4). Though the set of API's in SAPI4 specified direct interaction between applications and engines, and although this was a significant step forward in making speech recognition and speech synthesis technology more widely available, some of these API's were cumbersome to use, required the application to be apartment threaded, and did not support all languages.

The process of making speech recognition and speech synthesis more widely available has encountered other obstacles as well. For example, many of the interactions between the application programs and the engines can be complex. Such complexities include cross-process data marshalling, event notification, parameter validation, default configuration, and many others. Conventional operating systems provide essentially no assistance to either application vendors, or speech engine vendors, beyond basic access to audio devices. Therefore, application vendors and engine vendors have been required to write a great deal of code to interface with one another.

SUMMARY OF THE INVENTION

The present invention provides an application-independent and engine-independent middleware layer between applications and engines. The middleware provides speech-related services to both applications and engines, thereby making it far easier for application vendors and engine vendors to bring their technology to consumers.

In one embodiment, the middleware layer provides a rich set of services between speech synthesis applications and synthesis engines. Such services include parsing of input data into text fragments, format negotiation and conversion to obtain optimized data formats, selecting default values and managing data output to an audio device.

In another embodiment, the middleware layer manages single-application, multivoice processes. The middleware layer, in another embodiment, also manages multi-application, multivoice mixing processes.

In yet another embodiment, the invention includes a middleware component between speech recognition applications and speech recognition engines. In such an embodiment, the middleware layer illustratively generates a set of COM objects which configures the speech recognition engine, handles event notification and enables grammar manipulation.

In yet another embodiment, the middleware layer between the speech recognition application and speech recognition engine marshals calls from multiple application process to the speech recognition engine, and directs recognition results to the appropriate application process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a general computing environment in which the present invention may be practiced.

FIG. **2** is a block diagram of a speech recognition system in accordance with the present invention.

FIG. **3** is a more detailed block diagram of the TTS middleware component shown in FIG. **2**.

FIG. **4** is a flow diagram illustrating the general operation of the system shown in FIG. **3**.

FIG. **5** is a flow diagram illustrating format negotiation and conversion.

FIG. **6** is a more detailed block diagram of a multivoice implementation of the present invention.

FIG. **7** is a flow diagram illustrating the operation of the system shown in FIG. **6**.

FIG. **8** is a more detailed block diagram of a multiapplication, multivoice implementation of the present invention.

FIG. **9** illustrates a lexicon container object.

FIG. **10** is a flow diagram illustrating operation of the lexicon container object shown in FIG. **9**.

FIG. **11** is a more detailed block diagram of SR middleware component **210** shown in FIG. **2**.

FIG. **12** is a flow diagram illustrating the general operation of the system shown in FIG. **11**.

FIG. **13** is a flow diagram illustrating bookmarks.

FIGS. **14** and **15** are flow diagrams illustrating synchronization procedures.

FIG. **16** is a more detailed block diagram of a multiprocess data marshaling implementation of the present invention.

FIG. **17** is a flow diagram illustrating the data marshaling process.

Appendix A illustrates an exemplary set of APIs.

Appendix B illustrates an exemplary set of DDIs.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

FIG. **1** illustrates an example of a suitable computing system environment **100** on which the invention may be implemented. The computing system environment **100** is

only one example of a suitable computing environment and is not intended to suggest any limitation as to the scope of use or functionality of the invention. Neither should the computing environment **100** be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment **100**.

The invention is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well known computing systems, environments, and/or configurations that may be suitable for use with the invention include, but are not limited to, personal computers, server computers, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

The invention may be described in the general context of computer-executable instructions, such as program modules, being executed by a computer. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote computer storage media including memory storage devices.

With reference to FIG. **1**, an exemplary system for implementing the invention includes a general purpose computing device in the form of a computer **110**. Components of computer **110** may include, but are not limited to, a processing unit **120**, a system memory **130**, and a system bus **121** that couples various system components including the system memory to the processing unit **120**. The system bus **121** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus also known as Mezzanine bus.

Computer **110** typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by computer **110** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media includes both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computer **100**. Communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier WAV or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, FR, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer readable media.

The system memory **130** includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) **131** and random access memory (RAM) **132**. A basic input/output system **133** (BIOS), containing the basic routines that help to transfer information between elements within computer **110**, such as during start-up, is typically stored in ROM **131**. RAM **132** typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **120**. By way of example, and not limitation, FIG. **1** illustrates operating system **134**, application programs **135**, other program modules **136**, and program data **137**.

The computer **110** may also include other removable/non-removable volatile/nonvolatile computer storage media. By way of example only, FIG. **1** illustrates a hard disk drive **141** that reads from or writes to non-removable, nonvolatile magnetic media, a magnetic disk drive **151** that reads from or writes to a removable, nonvolatile magnetic disk **152**, and an optical disk drive **155** that reads from or writes to a removable, nonvolatile optical disk **156** such as a CD ROM or other optical media. Other removable/non-removable, volatile/nonvolatile computer storage media that can be used in the exemplary operating environment include, but are not limited to, magnetic tape cassettes, flash memory cards, digital versatile disks, digital video tape, solid state RAM, solid state ROM, and the like. The hard disk drive **141** is typically connected to the system bus **121** through a non-removable memory interface such as interface **140**, and magnetic disk drive **151** and optical disk drive **155** are typically connected to the system bus **121** by a removable memory interface, such as interface **150**.

The drives and their associated computer storage media discussed above and illustrated in FIG. **1**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **110**. In FIG. **1**, for example, hard disk drive **141** is illustrated as storing operating system **144**, application programs **145**, other program modules **146**, and program data **147**. Note that these components can either be the same as or different from operating system **134**, application programs **135**, other program modules **136**, and program data **137**. Operating system **144**, application programs **145**, other program modules **146**, and program data **147** are given different numbers here to illustrate that, at a minimum, they are different copies.

A user may enter commands and information into the computer **110** through input devices such as a keyboard **162**, a microphone **163**, and a pointing device **161**, such as a mouse, trackball or touch pad. Other input devices (not shown) may include a joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit **120** through a user input interface **160** that is coupled to the system bus, but may be connected by other interface and bus structures, such as a parallel port, game port or a universal serial bus (USB). A monitor **191** or other type of display device is also connected to the system bus **121** via an interface, such as a video interface **190**. In addition to the monitor, computers may

also include other peripheral output devices such as speakers **197** and printer **196**, which may be connected through an output peripheral interface **190**.

The computer **110** may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer **180**. The remote computer **180** may be a personal computer, a hand-held device, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the computer **110**. The logical connections depicted in FIG. **1** include a local area network (LAN) **171** and a wide area network (WAN) **173**, but may also include other networks. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

When used in a LAN networking environment, the computer **110** is connected to the LAN **171** through a network interface or adapter **170**. When used in a WAN networking environment, the computer **110** typically includes a modem **172** or other means for establishing communications over the WAN **173**, such as the Internet. The modem **172**, which may be internal or external, may be connected to the system bus **121** via the user input interface **160**, or other appropriate mechanism. In a networked environment, program modules depicted relative to the computer **110**, or portions thereof, may be stored in the remote memory storage device. By way of example, and not limitation, FIG. **1** illustrates remote application programs **185** as residing on remote computer **180**. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

FIG. **2** is a more detailed block diagram of a speech recognition system **200** in accordance with one embodiment of the of the present invention. It should be noted that speech recognition system **200** can be incorporated into the environment illustrated in FIG. **1**. Speech recognition system **200** includes one or more speech recognition applications **202**, speech middleware component **204**, one or more speech recognition engines **206** and one or more text-to-speech engines (synthesizers) **208**.

In one illustrative embodiment, speech middleware component **204** is implemented in the operating system **134** illustrated in FIG. **1**. Speech middleware component **204**, as shown in FIG. **2**, includes speech recognition middleware component **210**, context free grammar (CFG) engine **212** and text-to-speech middleware component **214**.

Briefly, in operation, speech middleware component **204** resides between applications **202** and engines **206** and **208**. Applications **202** can be speech recognition and speech synthesis applications which desire to invoke engines **206** and **208**. In doing so, applications **202** make calls to speech middleware component **204** which, in turn, makes calls to the appropriate engines **206** and **208** in order to have speech recognized or synthesized. For example, applications **202** may provide the source of audio data for speech recognition. Speech middleware component **204** passes that information to speech recognition engine **206** which simply recognizes the speech and returns a recognition result to speech recognition middleware component **210**. Speech recognition middleware component **210** places the result in a desired format and returns it to the application **202** which requested it. Similarly, an application **202** can provide a source of textual data to be synthesized. TTS middleware component **214** assembles that data, and provides it to TTS engine **208**, for synthesis. TTS engine **208** simply synthesizes the data and returns audio information to TTS middleware component **214**, which handles spooling of that information to an audio device, writing that information to memory, or placing that information in any other desired location, as specified by the application **202** which requested it.

CFG engine **212**, briefly, assembles and maintains grammars which are to be used by speech recognition engine **206**. This allows multiple applications and multiple grammars to be used with a single speech recognition engine **206**. This is discussed in greater detail later in the specification.

FIG. **3** is a more detailed block diagram of a portion of system **200** shown in FIG. **2**. Specifically, FIG. **3** illustrates TTS middleware component **214** in greater detail. TTS middleware component **214** illustratively includes a set of COM objects illustrated as the SpVoice object **216**, Site object **218** and lexicon container object **220**. In addition, TTS middleware component **214** can optionally include a format converter object **222** and an audio output object **224**. In one illustrative embodiment, communication between the objects in TTS middleware component **214** and applications **202** is accomplished using application programming interfaces (API). Similarly, communication between the objects in TTS middleware component **214** and the TTS engine object **208** is accomplished using device driver interfaces (DDIs). One illustrative embodiment of DDIs and APIs and their related structures is set out in Appendices A and B hereto.

A general discussion of the operation of TTS middleware component **214**, with applications **202** and engine **208**, is illustrated by the flow diagram in FIG. **4**. Initially, application **202** opens an instance of the SpVoice object **216**. In one illustrative embodiment, the application calls the COM CoCreateInstance for the component CLSID_SpVoice to get a pointer to the interface ISpVoice of the SpVoice object. SpVoice object **216** then creates lexicon container object **220** and an XML parser object **228**. This is indicated by blocks **230**, **232** and **234** in FIG. **4**.

Next, application **202** can either specify the attributes of TTS engine **208**, such as whether the engine which is the synthesizer exhibits male or female voice qualities, the language of the synthesis, etc. This is done, for example, by calling the SetVoice method on the SpVoice object **216**. This is indicated by optional block **236** in FIG. **4**. In addition, the application can optionally specify the particular audio output object **224** which is desired. This is indicated by optional block **238** in FIG. **4**.

The application **202** can set other attributes associated with the voice speaking, such as the rate and volume of speech, using for example, the SetRate and the SetVolume methods exposed by the SpVoice object **216**. These are optional as well.

It should be noted that specifying the attributes of the engine **208** and audio output object **224** are optional. If the application does not specify these items, the first call to the SpVoice object **216** requiring synthesis results in the SpVoice object **216** choosing and initializing the default voice (i.e., the default TTS engine **208**) and the default audio output object **224**.

Once these items are configured properly, application **202** can call the SpVoice object **216** and request that textual information by synthesized. This can be done, for example, by calling the Speak or the SpeakStream methods on the SpVoice object **216**. This is indicated by block **240**.

The SpVoice object **216** then performs format negotiation. This is discussed in greater detail later in the specification with respect to FIG. **5**. Briefly, however, the SpVoice object **216** attempts to optimize the format of data created by TTS

engine **208** and that accepted by audio output object **224** for optimal synthesis. Format negotiation is indicated by block **242** in FIG. **4**.

The SpVoice object **216** then breaks the textual information provided by application **202** into text fragments. For example, if the textual information is in XML, the SpVoice object **216** invokes the XML parser **228** to parse the XML input into text fragments. While the textual information can come from a variety of sources (such as a text buffer, straight textual information, XML, etc.) that information is broken into text fragments by SpVoice object **216**, as indicated by block **244** in FIG. **4**.

The SpVoice object **216** then calls a speak method on TTS engine **208**, passing in the information to be synthesized. This is indicated by block **246**. In doing this, the SpVoice object **216** also specifies a Site object **218** to be used by the TTS engine for returning the synthesized information.

TTS engine **208** receives the text fragments, synthesizes the text into WAV data (or other suitable audio data) and provides an indication of where events occur in the WAV data. For example, TTS engine **208** can illustratively provide an indication where word and phoneme boundaries occur in the WAV data. This information is all provided from TTS engine **208** to SpVoice object **216** through the Site object **218**.

It should be noted that, in performing the synthesis, TTS engine **208** can access the lexicon object **220** contained in TTS middleware component **214**. This is discussed in greater detail later in the specification with respect to FIGS. **9** and **10**. Briefly, the lexicon container object **220** contains all lexicons of interest and the TTS engine **208** simply needs to access object **220** as if it were a single lexicon.

Synthesizing the actual fragments and writing them to the Site object are indicated by blocks **248** and **250** in FIG. **4**.

During the format negotiation step **242**, the SpVoice object **216** determines whether the format of the audio output object **224** or the format of the information provided by TTS engine **208** need to be converted. If conversion is required, information is provided to format converter object **222**, such as through the ISpAudio or ISpStream interfaces, where the information is converted into a desired format for the audio output object **224**. Format converter object **222** then manages the process of spooling out the audio information to audio output object **224** and also manages returning events noticed by the audio output object **224** to the Site object **218** and the SpVoice object **216** for transmission back to the application **202**. This is indicated by blocks **252** and **254** in FIG. **4** Where no format conversion is desired, the information from the Site object **218** is spooled out to the audio output object **224** by the SpVoice object **216**, through a suitable interface such as the IspStream interface. This is indicated by block **256**.

Of course, it should also be noted that rather than providing the information directly to an audio output object **224**, the information can be written to memory, as indicated by block **258**, or provided at some other specified output or location as indicated by block **260** in FIG. **4**.

FIG. **5** is a flow diagram illustrating the process of format negotiation and conversion (illustrated by blocks **242** and **254** in FIG. **4**) in greater detail. In order to optimize the format used by TTS engine **208** and audio output object **224**, SpVoice object **216** first determines whether the application has specified an audio output device object **224**. If not, the default device object is initiated. This is indicated by blocks **262** and **264** in FIG. **5**. If the application **202** specifies an audio output object **224**, the application can also indicate whether it is acceptable to use a different format on that device, rather than the default format of the specified device.

In any case, once the appropriate audio output object **224** is initiated, SpVoice object **216** queries the audio output object **224** to obtain the default format from the audio output object **224**. Obtaining the default format from the audio device object **224** is indicated by block **266** in FIG. **5**.

Once the default format of information expected by the audio output object is obtained, the SpVoice object **216** queries TTS engine **208** to see what format it will provide based on the format that is input to it. This is indicated by block **268**. It is next determined whether the output from TTS engine **208** is in the proper format to be received by the input to the audio output object **224**. This is indicated by block **270**. If the output format from TTS engine **208** matches the desired input format at audio output object **224**, the information can be output in that format, to audio output object **224**. This is indicated by block **272**.

However, if, at block **270**, it is determined that the output format from TTS engine **208** is not the same as the desired input format at audio output object **224**, then the SpVoice object **216** determines whether it can reconfigure the audio output object **224** to accept the format output by TTS engine **208**. This is indicated by block **274**. Recall that, if the application specifies an audio output object **224** it can also specify that the input format not be changed.

If, at block **274**, it is admissible to change the input format expected by the audio output object **224**, then the audio output object **224** is simply reconfigured to accept the format output by TTS engine **208**. This is indicated by block **276**. The information can then be provided to the audio output object **224** as indicated by block **272**.

However, if it is determined at block **274** that the expected input format of the audio output object **224** cannot be changed, the SpVoice object **216** determines whether a format converter **222** is available for converting the output format from the TTS engine **208** to the desired input format of audio output object **224**. This is indicated by block **278**. If no such converter is available, SpVoice object **216** simply provides an error message to application **202** indicating that the format conversion cannot be made. However, if a format converter is available to make the desired format conversion, the format converter is invoked so that the audio information from TTS engine **208** can be converted to the appropriate format. This is indicated by block **280**. In that case, the converted audio information is provided from format converter object **222** to the audio output object **224**, as indicated by block **272**.

FIG. **6** is a more detailed block diagram of another embodiment of TTS middleware component **214** illustrating another feature of the present invention. A number of the items shown in FIG. **6** are similar to those shown in FIG. **3** and are similarly numbered. However, there are some differences. FIG. **6** illustrates an embodiment in which an application may wish to invoke two different voices. In other words, in a game or other application, there may be a desire to implement text-to-speech for two different types of speakers (e.g., male and female, two different types of same-gender voices, two different languages, etc.).

In order accomplish this, the application first performs the same first several steps illustrated in the flow diagram of FIG. **4**. For example, the application first opens SpVoice object **216**, which in turn creates the lexicon and XML parsers. These steps are not shown in FIG. **7** for the sake of clarity. The application **202** then specifies the engines, or the attributes of the voices which the application desires. This is indicated by block **282**.

Setting the attributes of the engine (or the voice) can be done, for instance, by calling the method SetVoice on SpVoice object **216**. In response to these specified voices, SpVoice object **216** instantiates two different TTS engine objects **208**A and **208**B, which contain the desired attributes specified by the application. Therefore, for example, if the application **202** specifies one male voice and one female voice, SpVoice object **216** instantiates a TTS engine **208**A which has attributes of a female voice and TTS engine **208**B which has attributes of a male voice. This is indicated by block **284**. Application **202** also sets the priority for those specified voices (or engines). This is indicated by block **286**. The priority basically indicates which TTS engine takes precedence in speaking, and is described in greater detail below. Setting the priority can be called, for instance, by invoking the method SetPriority on the SpVoice object **216**.

Once the engines have been instantiated and the priorities set, the application indicates to the SpVoice object **216** that is wishes some textual information to be spoken. This is indicated by block **288** and can be done, for example, by calling Speak or SpeakStream on the SpVoice object **216**. The information provided will also identify the particular engine **208**A or **208**B which application **202** wishes to have speak the information.

The textual input information is then parsed into text fragments as indicated by block **290**. For example, if the input is an XML input, the XML is parsed into text fragments.

Based on the indication from application **202** (such as an XML tag on the input information) SpVoice object **216** calls the appropriate TTS engine **208**A or **208**B requesting synthesis and passing in the information to be synthesized. This is indicated by block **292**. The TTS engine **208**A or **208**B which has been called, synthesizes the text fragments and writes the audio information to its corresponding Site object **218**A or **218**B. This is indicated by block **294**. The synthesized information is then provided from Site **218**A or **218**B to audio output object **224** which provides it in turn to an audio device, such as speaker **296** or to another set of API's or objects, as desired.

It should be noted that, in setting priority as shown in block **286**, a number of different things can be accomplished. If the priorities are set to normal, then the requests by application **202** to speak text are simply queued and are spoken in the order received. However, other priorities can be set as well. If a priority is set to alert, an audio message can be injected, in the middle of another audio message which is playing. Similarly, if the priority is set to speakover, then that audio text will simply speak at the same time as the audio which is currently being spoken.

The priorities are better illustrated with respect to FIG. **8**. FIG. **8** shows a multiprocess, multivoice implementation of the present invention. In FIG. **8**, two applications **202**A and **202**B have created two separate instances of the SpVoice object **216**A and **216**B. Those objects have created separate grammar container objects **220**A and **220**B as well as separate Site objects **218**A and **218**B, TTS engine objects **208**A and **208**B and audio objects **224**A and **224**B. The outputs from the audio output objects **224**A and **224**B are provided to a multimedia application programming interface (API) **300**, such as that supported by the WINDOWS98 operating system, Second Edition or by the WINDOWS2000 operating system. The output of the multimedia API **300** is provided to an audio device, such as speaker **302**.

The operation of processes A and B shown in FIG. **8** is similar to that illustrated by FIGS. **3**–**5** discussed above. It should also be mentioned, however, that in addition to setting the priority for a given voice, or TTS engine, the application can also specify the insertion points in a synthesized stream for alerts. Therefore, in one example, assume that application **202**A has specified its request to speak as having a normal priority, and application **202**B has specified its request to speak as having an alert priority, and further assume that audio output object **224**A is speaking data which is being spooled out by either SpVoice object **216**A or Site object **218**A. Now assume that TTS engine **208**B returns synthesis information which has been prioritized with an alert priority. Audio output object **224**A will be allowed to speak to the alert boundary set by application **202**A (such as the end of the current word) at which point the audio output object **224**A will be closed and control will be assumed by SpVoice object **216**B and audio output object **224**B such that only its information can be output to multimedia API **300** and subsequently to speaker **302**. This can be accomplished using a shared mutex scheme such as that provided through WinAP services. When audio output object **224**A is closed, the SpVoice object **216**A simply does not return on the call which TTS engine **208**A has made to Site **218**A. Therefore, TTS engine **208**A simply pauses. After the alert message has been spoken, SpVoice object **216**B and audio output object **224**B release the mutex such that SpVoice object **216**A and audio output object **224**A can continue speaking. At that point, SpVoice object **216**A returns on the TTS engine call such that TTS engine **208**A can continue its processing.

If the two speak commands by applications **202**A and **202**B are indicated as speakover priority, then assuming that the multimedia API layer **300** supports mixing, the audio information from both audio output object **224**A and audio object **224**B will be spoken by speaker **302**, at the same time. If the speak requests are indicated as normal, then the speak requests are queued and are spoken, in turn.

It should also be noted that if, within either process A or process B multiple speak requests are received, then processing is handled in a similar fashion. If a normal speak request is followed immediately by an alert request, than the normal speak request is halted at an alert boundary and the alert message is spoken, after which the normal speak request is again resumed. If more then one alert message is received within a single process, the alert messages are themselves queued, and spoken in turn.

It should also be noted that the configuration illustrated in FIG. **8** can be implemented by one application **202**, rather than two applications. In that case, a single application **202** simply co-creates two instances of the SpVoice object **216**. Those instances create the remaining objects, as illustrated in FIG. **8**.

FIG. **9** is a more detailed block diagram illustrating the lexicon container object **220** shown and discussed in the above Figures. Lexicon container object **220** illustratively contains a plurality of lexicons, such as user lexicon **400** and one or more application lexicons **402** and **404**. In accordance with one aspect of the present invention, certain applications can specify lexicons for use by the TTS engine **208**. For example, such lexicons may contain words that have pronunciations which are not obtainable using normal letter-sound rules. In addition, a user may have a specified lexicon containing words which the user commonly uses, and which are not easily pronounceable and for which the user has a desired pronunciation. Such user lexicons can be changed through the control panel.

In any case, once the lexicon container object **220** is created, it examines the registry for user and application lexicons. Lexicon container object **220** can also expose an

interface **406** accessible by TTS engine **208**. This allows the TTS engine **208** to not only access various lexicons **400**, **402** and **404** stored in lexicon container object **220**, but also allows TTS engine **208** to add a lexicon to lexicon container object **220** as well. Lexicon container object **220** represents all of the lexicons contained therein, as one large lexicon to TTS engine **208**. Therefore, TTS engine **208** or application **202** need not handle providing access to multiple lexicons, as that is all handled by lexicon container object **220** through its exposed interface.

FIG. **10** is a flow diagram illustrating operation of lexicon container **220** and TTS engine **208**. In operation, once TTS engine **208** has obtained a synthesized word as indicated by block **408** in FIG. **10**, it accesses lexicon container object interface **406** to determine whether a user or application has specified a pronunciation for that word, as indicated by block **410**. If so, it changes the audio data created by it to reflect the pronunciation contained in lexicon container object **220** and provides that information to its Site **218**. This is indicated by block **412**.

This provides significant advantages. For example, in the past, TTS engines **208** contained the lexicon. If a user had terms with user-specified pronunciations, every time an application opened up a separate TTS engine that engine would speak the user's pronunciations improperly, until the TTS engine lexicon was modified. In contrast, using lexicon container object **220**, each time a different TTS engine **208** is opened, it will automatically be directed to the user lexicon **400** such that the user's preferred pronunciations will always be used, regardless of the TTS engine **208** which is opened. This engine-independent lexicon thus greatly improves the process.

FIG. **11** is a more detailed block diagram of a portion of system **200** as shown in FIG. **2**. More specifically, FIG. **11** illustrates SR middleware component **210** in greater detail. In the embodiment illustrated in FIG. **11**, SR middleware component **210** includes a SpRecoInstance object **420** which represents an audio object (SpAudio **422**, which provides an input audio stream, and its processor) and a speech recognition (SR) engine **206**. SR middleware component **210** also includes SpRecoContext object **424**, SpRecoGrammar object **426**, SpSite object **428** SpRecoResult object **430** and SpRecognizer object **432**. The SpRecoContext object **424** is similar to the SpVoice object **216** in TTS middleware component **214** in that it generally manages data flow, and performs services, within SR middleware component **210**. SpRecoContext object **424** exposes an interface which can be used to communicate with application **202**. SpRecoContext object **424** also calls interface methods exposed by SR engine object **206**.

The SpRecoGrammar object **426** represents the grammar which the SR engine **206** associated with the SpRecoGrammar object **426** will be listening to. The SpRecoGrammar object **426** can contain a number of different items, such as a dictation topic grammar, a context free grammar (CFG), a proprietary grammar loaded either by SR engine **206** or application **202** and a word sequence data buffer which is explained in greater detail later in the specification.

FIG. **12** is a flow diagram which illustrates the general operation of the embodiment of the SR middleware component **210** as illustrated in FIG. **11**. First, application **202** opens the SpRecoInstance object **420** which creates an instance of SR engine **206** and the audio input object **422**. Again, as with text-to-speech implementations, the application can request a specific SR engine **206** and audio engine **422**. If one is not specified, the default objects are automatically initiated. This is indicated by block **440** in FIG. **12**.

The SpRecoContext object **424** is then created as illustrated by block **442** in FIG. **12**. The application can then call exposed interfaces on SpRecoContext object **424** to create the SpRecoGrammar object **426**. Such an interface can include, for instance, the CreateGrammar method. Creation of the SpRecoGrammar object is illustrated by block **444** in FIG. **12**.

The application then calls the SpRecoContext object **424** to set desired attributes of recognition, as indicated by block **446**. For example, the application can determine whether it would like alternatives generated by SR engine **206** by calling the SetMaxAlternative method and can also enable or disable the retention of the audio information along with the results. In other words, SR middleware component **210** will retain the audio information which is provided by audio object **422** upon which SR engine **206** performs recognition. That way, the audio information can be reviewed later by the user, if desired. The application can also call interfaces exposed by the SpRecoContext object **424** in order to change the format of the retained audio. Otherwise, the default format which was used by the recognition engine **206** in performing recognition is used.

The application then illustratively configures the SpRecoGrammar object **426** as desired. For example, the application **202** can load a grammar into the SpRecoGrammar object by calling the LoadDictation method. The application can also set a word sequence data buffer in engine **206** by calling the SetWordSequenceData method. Further, the application can activate or deactivate grammar rules by either rule ID or by rule name, by calling the SetRuleIDState method or the SetRuleState method, respectively. The application can also enable or disable grammars within the SpRecoGrammar object **426** by calling the SetGrammarState method. It should be noted that, when a grammar is disabled, the SpRecoGrammar object **426** stores the state of the grammar prior to it being disabled. Therefore, when it is again enabled, the SpRecoGrammar object can automatically activate and deactivate rules in that grammar to obtain its previous activation state. Further, the application can load command and control grammars by calling the LoadCmdFromXXXX where "XXXX" can be a file, object, resource or memory. Configuring the SpRecoGrammar object is indicated by block **448** in FIG. **12**.

The SpRecoContext object **424** then performs a format negotiation as indicated with the speech synthesis embodiment. In other words, the SpRecoContext object **424** queries the audio input object **422** to determine the format of the audio input. The SpRecoContext object **424** also quires SR engine **206** to determine what format it desires, and will reconfigure the audio object **422** or the SR engine **206** as desired, if possible. The format negotiation is indicated by block **450** in FIG. **12**.

SpRecoContext object **424** then calls device driver interfaces exposed by SR Engine **206** to configure the engine and to set SrEngineSite **428**, as indicated by block **452**. The Site for the engine to use is set by calling the SetSite method on SR engine **206**. This provides the handle to Site object **428** which is the object that SR engine **206** calls to communicate events and recognitions as well as to synchronize with and make other communications with, SR middleware component **210**.

Acoustic recognition information is also set in engine **206** by, for instance, calling the SetRecoProfile method exposed by engine **206**. The acoustic profile information may vary, for example, with user, or with application. Therefore, the appropriate acoustic profile information is obtained from the registry and loaded into SR engine **206**.

The engine can also be loaded with specific or proprietary grammars or language models by calling the LoadProprietaryGrammar method or the LoadSLM method, respectively. The SpRecoContext object **242** can also set up a text buffer structure and hand SR engine **206** a pointer to it by calling the OnCreateGrammar method and can also set a word sequence data buffer in engine **206** by calling the SetWordSequenceData method.

The word sequence data buffer is a buffer which can be populated, on-the-fly, by the application. In one illustrative embodiment the word sequence data buffer contains double null terminated entries which can be used by SR engine **206** in making a recognition. For example, a CFG rule, which spawns a recognition by SR engine **206**, can point SR engine **206** into the word sequence data buffer to look for matches of subsequent word sequences. In one illustrative embodiment, such a rule may spawn a recognition of the words "Send e-mail to". In that case, the application can populate the word sequence data buffer with electronic mail aliases. SR engine **206** then searches the word sequence data buffer to better refine the recognition process in making a recognition of the following speech.

Once SR engine **206** is configured, the SpRecoContext object **424** can call SR engine **206** to begin recognition. Such a call can be made on, for example, the RecognizeStream method. When such a method is called, SR engine **206** begins recognition on an input data stream and the process continues until a buffer containing the data to be recognized is empty, or until the process is affirmatively stopped. Beginning recognition is illustrated by block **454** in FIG. **12**.

During recognition, SR engine **206** illustratively calls Site object **428** with intermittent updates. This is indicated by block **456**. The Site object **428** exposes interfaces which are called by SR engine **206** to return these intermittent updates, to get audio data for recognition, and to return sound events and recognition information. For example, SR engine **206** calls the Site object to indicate when a sound has begun, and when it has ended. The SR engine **206** also calls Site to provide the current position of recognition in the input stream, such as by calling the UpdateRecoPos method. SR engine **206** can also call the Synchronize method to process changes in the state of its active grammar. In other words, the application may have changed the state of the active grammar in the SpRecoGrammar object being used by SR engine **206** during recognition. Therefore, SR engine **206** periodically calls Synchronize to stop processing and update the state of its active grammar. This can be done by obtaining word, rule, and state transition information for CFG rules, words and transitions in the SpRecoGrammar object **426**. It does this, for example, by calling the GetRuleInfo, GetWordInfo, and GetStateInfo methods on the Site object.

SR engine **206** also illustratively calls Site **428** when either a recognition hypothesis or an actual final recognition has been obtained, by calling the Recognition method and either setting or resetting a hypothesis flag contained in the input parameters for the method. Once the final result is obtained, it is returned to Site **428** by calling the Recognition method and indicating that data is available, and by having the hypothesis flag reset. This is indicated by block **458** in FIG. **12**. Of course, it should also be noted that where alternatives are requested, SR engine **206** passes those alternatives back to Site **428** along with the result.

Once Site contains the information indicating a final recognition, CFG engine **212** creates a complex result from the recognition information. The application **202** can then obtain the recognition result by calling the SpRecoResult object **430** or an associated SpPhrase object (not shown). For example, on the SpPhrase object, the application can call the GetPhrase or GetText methods which retrieve data elements associated with the phrase. The application can also obtain elements associated with alternatives and replace the original phrase with the alternatives by calling the GetAltInfo method and the Commit method, respectively.

One illustrative data structure which identifies a recognized result is as follows:

SPPHRASE

Typedef [restricted] struct SPPHRASE

ULONG	cbSize;
LANGID	LangID;
WORD	wReserved;
ULONGLONG	ftStartTime;
ULONGLONG	ullAudioStreamPosition;
ULONG	ulAudioSizeBytes;
ULONG	ulAudioSizeTime;
SPPHRASERULE	Rule;
const SPPHRASEPROPERTY	*pProperties;
const SPHRASEELMENT	*pElements;
ULONG	cReplacements;
const SPPHRASEREPLACEMENT	pReplacements;
GUID	SREngineID;
ULONG	ulSREnginePrivateDataSize;
const BYE	*pSREnginePrivateData;
SPPHRASE	

MEMBERS

cbSize—The size of this structure in bytes.

LangID—The language ID of the current language.

WReserved—Reserved for future use.

FtStart Time—The start time of the recognition in the input stream.

UllAudioStreamPosition—The start position of the recognition in the input stream.

UlAudioSizeBytes—The size of audio information.

UlAudioSizeTime—The time of audio information.

Rule—The rule that spawned this result.

pProperties—The pointer to the semantic properties for the rule that spawned this result.

pElements—The pointer to the elements of the result.

pReplacements—The pointer to the replacement elements.

SREngineID—The ID of the SR engine which produced the results.

UlSREnginePrivateDataSize—The size of any proprietary data sent by the SR engine.

PSREnginePrivateData—The pointer to the proprietary data.

Application **202** can also set book marks in the audio stream to be recognized. For example, the application **202** may desire a bookmark so that it can note cursor position when the user clicks the mouse, as this event is temporally related to the audio stream. Therefore, the application calls the Bookmark method exposed by the SpRecoContext object to set a bookmark within the current recognition stream. Because SR engine **206** in intermittently calling Site **428** with updates as to its position within the recognition steam, the SpRecoContext object **424** can determine when the SR engine **206** has reached the bookmark. When this happens, an event **500** is added to the event queue which is communicated back to application **202**. This allows application **202** to coordinate its state with events coming back from SR engine **206**.

This can be quite useful in speech recognition applications. For example, a user manipulation of the mouse can change the state of the application. However, prior to actually changing the state of the application, the application may wish to wait until SR engine **206** has reached the same temporal point in the recognition stream. This allows the application to synchronize with SR engine **206** exactly where the application desires to take action.

FIG. **13** is a flow diagram better illustrating this process. First, the application **202** calls the SpRecoContext object **424** (illustratively the Bookmark method) to set a bookmark within the current recognition stream. This is indicated by block **502**. The SpRecoContext object **424** sets the bookmark in the specified stream position as indicated by block **504**. When the speech recognition engine **206** reaches the bookmark location, an event is returned to the event queue. This is indicated by block **506**. The SpRecoContext object **424** then returns the bookmark event to application **202** as indicated by block **508**.

Application **202** can also cause SR engine **206** to pause and synchronize with it in another way. FIG. **14** is a flow diagram which better illustrates this. Application program **202** calls a method (such as the Pause method) exposed by the SpRecoContext object **424** to stop SR engine **206** for synchronization. This is indicated by block **510**. On the next call from the SR engine **206** to Site, the SpRecoContext object **424** does not return on that call to the SR engine **206** until the SR application **202** has said to resume recognition. This is indicated by block **512**. At that time, the application can do necessary work in updating the state of the active grammar or loading another grammar to be used by SR engine **206** as indicated by block **514**. During the pause mode, the SR engine **206** still calls the sync method exposed by Site **428**, and asks it for updates to its active grammar as discussed above. This is indicated by block **516**. After the synchronization has been completed, the SpRecoContext object **420** returns to the application **202** and the application calls Resume on SpRecoContext object **420**. This is indicated by block **518**. In response, SpRecoContext object **424** returns on the SR engine call so that the SR engine can continue processing.

FIG. **15** is another flow diagram illustrating yet another way in which SR engine **206** can synchronize with application **202**. Individual rules in the SpRecoGrammar object **426** can be tagged as autopause rules. When SR engine **206** recognizes one of these rules, the SR engine **206** is set into a pause state while the application **202** changes grammars. When the application is finished and calls resume, the SR engine now has the appropriate grammar to continue recognition.

Therefore, SR engine **206** first returns a result to Site **428**. This is indicated by block **520**. The SpRecoContext object **424** calls Site **428** to find that the rule which fired to spawn the recognition is an autopause rule. This is indicated by block **522**. The SpRecoContext object **424** then notifies application **202** and does not return on the SR engine **206** at that time. This effectively pauses SR engine **206**, and audio input is buffered in the meantime. This is indicated by block **524**.

During this pause state, application **202** updates the grammar rules, words, transitions, etc., as desired. This is indicated by block **526**. Because a recognition event is also a synchronize event, SR engine **206** still calls Site **428** while in the pause mode. This is indicated by block **528**. Thus, the SR engine obtains the updated state of its active grammar.

The application **202** then calls Resume on SpRecoContext object **424**, as indicated by block **530**. The SpRecoContext object then returns on the recognition call from SR engine **206**, allowing SR engine **206** to continue recognition. This is indicated by block **532**.

FIG. **16** is a block diagram of a multiprocess implementation of the present invention. It may be desirable to have multiple applications implementing speech recognition technology at the same time. For example, it may well be desirable to use a command and control application which implements command and control steps based on speech commands. Similarly, it may be desirable to have another application, such as a word processing application, implementing speech recognition at the same time. However, it is also recognized that it may be desirable to have only a single arbiter determining what is actually said (i.e., it is desirable to have only a single speech recognition engine recognizing speech).

FIG. **16** indicates applications **202**A and **202**B. Many of the other contents in the block diagram are similar to those shown in FIG. **11**, and are similarly number. However, the A and B suffixes indicate whether the objects are associated with process A or process B illustrated in FIG. **16**. FIG. **16** also illustrates that the audio input object **422** and the SR engine **206** are part of the shared process so that only a single instance of each needs to be initiated. FIG. **16** further illustrates SAPI server **600** which can be implemented, as an executable program, for marshaling the delivery of recognized speech to the appropriate recognition process.

FIG. **17** is a flow diagram illustrating data marshaling between processes. Both processes operate substantially as described with respect to FIG. **11**, except both use audio input object **422** and SR engine **206**. Therefore, one of the SpRecoContext objects first calls SR engine **206** on RecognizeStream. This is indicated by block **602** in FIG. **17**. The SR engine then calls on Site **428** to synchronize and to obtain updates to its active grammar. This is indicated by block **604**. The SR engine then begins its synchronization of the input data, as indicated by block **606**.

SR engine **206** then returns preliminary information (such as its position within the recognition stream, when sound has been heard and has ended, and hypotheses). This is indicated by block **608**. The SAPI server **600** notifies all applications **202**A and **202**B, which are currently operating, of the events returned by SR engine **206**. SAPI server **600** illustratively does this through the RecoContext objects associated with the applications. This is indicated by block **610**.

SR engine **206** then returns a result by calling the Recognition method exposed by Site **428**. This is indicated by block **612**. SAPI server **600** then determines whether it is a hypothesis (e.g., a preliminary result) by examining the hypothesis bit in the result returned by SR engine **206**. This is indicated by block **614**. If it is a hypothesis, then SAPI server **600** sends a global notification to all SpRecoContext objects that a hypothesis result has been received, and waits for a finally recognized result. This is indicated by block **616** and **618**.

If, at block **614**, it is determined that the result is final, then SAPI server **600** sends a global notification to all SpRecoContext objects indicating that a final result has been received. This is indicated by **620**.

To better understand the remaining process, a brief discussion of CFG engine **212** may be helpful. The operation of CFG engine **212** is described in greater detail in copending U.S. patent application Ser. No. 09/751,613 which corresponds to U.S. Pat. No. 6,957,184. Briefly, for the sake of completeness, CFG engine **212** combines all grammars from all applications and RecoContext objects and combines them into a single set of grammars which is communicated to SR

engine **206**. Therefore, the single SR engine **206** only sees a large collection of words, rules, and transitions which it is to recognize. In maintaining the collection of grammars, CFG engine **212** maintains an indication as to where the grammars came from (i.e., which process they came from).

Recall that when SR engine **206** returns its results, it indicates the rule which fired to spawn the result. Therefore, by examining the rule identifier (or rule name) that fired to spawn the result, CFG engine **212** can identify the particular SpRecoGrammar object which the rule came from. The CFG engine **212** can then call methods exposed by that SpRecoGrammar object to obtain the SpRecoContext object associated with that grammar (such as by calling the GetRecoContext method). Identifying the grammar which the rule came from, and identifying the SpRecoContext object associated with that grammar is indicated by blocks **622** and **624**, respectively.

This information is passed to SAPI server **600**, which in turn notifies the SpRecoContext object associated with that grammar. The notification indicates that its result has been recognized. That SpRecoContext object can then notify its application and pass the recognition event on to the application, as indicated by block **626**.

In conclusion, it can be seen that the middleware layer between the applications and engines provides many services for both the applications and engines, which had previously been performed by either the application or the engine. The present middleware layer does this in an application-independent and engine-independent manner.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A multi-process speech recognition middleware layer of computer-readable instructions embedded on a computer-readable medium, the instructions being configured to, when executed, facilitate communication between a speech recognition (SR) engine and a plurality of speech recognition applications, the middleware layer comprising:

a first process associated with a first speech recognition application including:

a first context object having an application interface to enable application control of a first plurality of attributes of the speech recognition engine, the first context object also including an engine interface; and

a first grammar object storing a first grammar used by the first process to support a speech recognition functionality associated with the first speech recognition application; and

a second process associated with a second speech recognition application that is different than the first speech application, wherein the second process includes:

a second context object having an application interface to enable application control of a first plurality of attributes of the speech recognition engine, the second context object also including an engine interface; and

a second grammar object storing a second grammar used by the second process to support a speech recognition functionality associated with the second speech recognition application; and

a server process configured to receive result information provided by the SR engine and provide the result information to the first or second process, to which the result information belongs.

2. The multi-process speech recognition middleware layer of claim **1** wherein the first and second grammars each include a plurality of rules and further comprising:

a grammar engine configured to store a grammar indication indicating the grammar to which each of the plurality of rules belong.

3. The multi-process speech recognition middleware layer of claim **2** wherein the SR engine returns, along with the result information, a rule identifier identifying a rule which spawned the result information.

4. The multi-process speech recognition middleware layer of claim **3** wherein the grammar engine examines the rule identifier to determine a particular grammar to which the identified rule belongs.

5. The multi-process speech recognition middleware layer of claim **1** wherein the server process queries the first or second grammar object containing the particular grammar to receive an identity of an associated context object.

6. The multi-process speech recognition middleware layer of claim **5** wherein the server process notifies the associated context object that the result belongs to its associated process.

7. The multi-process speech recognition middleware layer of claim **1** wherein the SR engine returns preliminary information to the server process and wherein the server process is configured to notify the first and second context objects of the preliminary information.

8. A multi-voice speech synthesis middleware layer of computer-readable instructions embedded on a computer-readable medium, the instructions being configured to, when executed, facilitate communication between one or more applications and a plurality of text-to-speech (TTS) engines, the middleware layer comprising:

at least a first voice object having an application interface configured to receive TTS engine attribute information from the application and to instantiate first and second TTS engines based on the TTS attribute information, to receive a speak request requesting at least one of the TTS engines to speak a message, and to receive priority information associated with each speak request indicative of a precedence each speak request is to take, and wherein the first voice object has an engine interface configured to call a specified one of the first and second TTS engines to synthesize input data.

9. The multi-voice speech synthesis middleware layer of claim **8** wherein the at least first voice object is configured to receive a normal priority associated with a message and to call the TTS engines so the message with normal priority is spoken in turn.

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