ECE 478-578
Intelligent Robotics I

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Introduction to ROS Part – 4
&
Spoken Language Interface Technologies

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Course Structure

- **Part 1 - Overview**
  - What is ROS?
  - Introduction to ROS
  - ROS architecture, philosophy, history
  - How to install ROS?
  - Examples
  - Installation
  - ROS Master
  - ROS Nodes
  - ROS Topic
  - ROS Messages
  - Console Commands
  - ROS Packages
  - ROS Launch-files
  - Catkin Workspace and Build System
  - Turtlesim
- **Part 2 - Basics**
  - ROS File System
  - ROS Package
  - How to create a package?
  - How to build a package?
  - Creating a Publisher Node
  - Creating a Subscriber Node
  - Assignment 3
- **Part 3 - Debug**
  - ROS Launch File
  - How to use ROS .bagfiles?
  - ROS Parameters
  - ROS Namespace
- **Part 4 - Speech**
  - ROS Services
  - ROS Messages
  - Speech Recognition
  - Speech Synthesis
  - Google Dialogflow
- **Part 5 - Fuzzy**
  - Amazon Polly
  - ROS Actions
  - Rviz
  - Mapping
  - Localization
  - Fuzzy Logic
  - 2D Multi-Robot Simulator
  - Assignment 4

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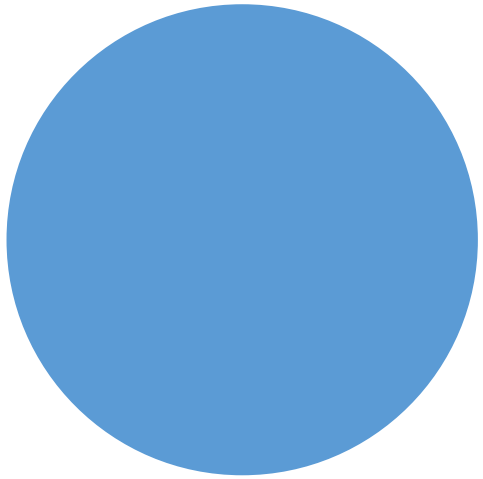

ROS
(Robot Operating System)

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ROS Services

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ROS Service

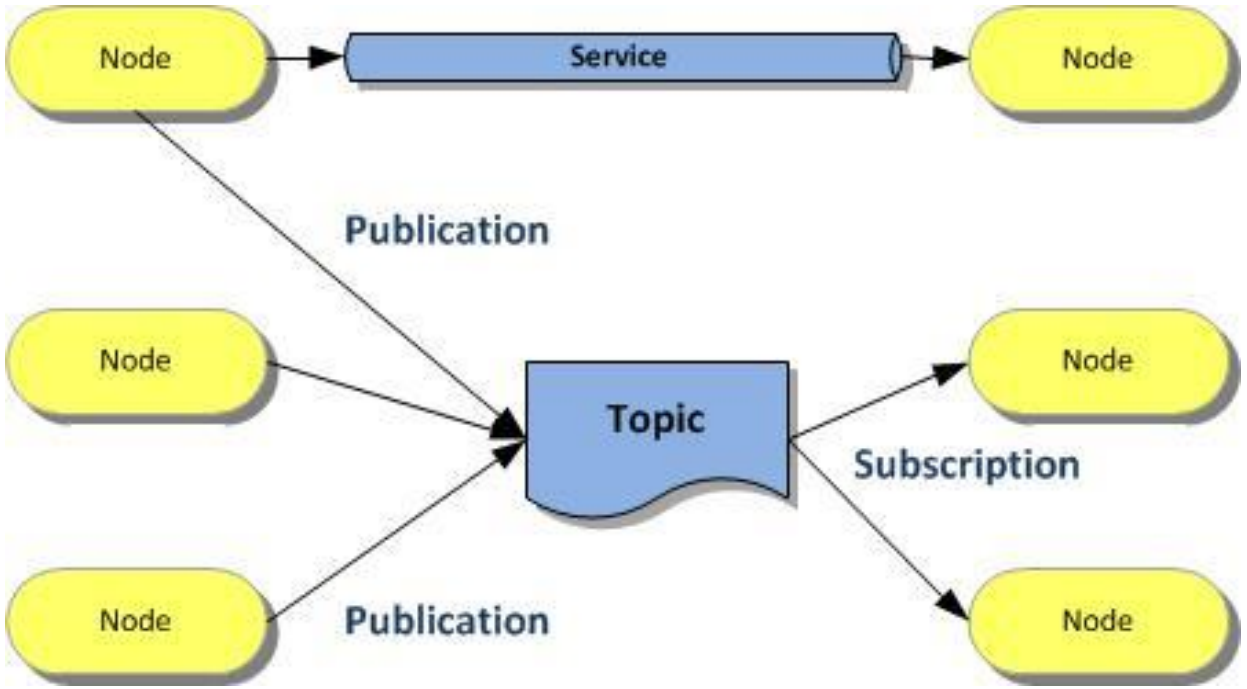
- In some robot applications, a publish/subscribe model will not be enough if it needs a request/response interaction.
- The publish/subscribe model is a kind of one-way transport system and when we work with a distributed system, we might need a request/response kind of interaction.
- We can define a service definition that contains two parts;
  - one is for requests
  - the other is for responses.
- Using ROS Services, we can write a server node and client node. The server node provides the service under a name, and when the client node sends a request message to this server, it will respond and send the result to the client.
- The client might need to wait until the server responds. The ROS service interaction is like a remote procedure call.

ROS Service

- The publish/subscribe model is a very flexible.
- However, its many-to-many one-way transport is not appropriate for RPC request / reply interactions, which are often required in a distributed system.
- Request / reply is done via a *Service*
- They are defined by a pair of messages: one for the request and one for the reply.
- Services are defined using srv files, which are compiled into source code by a ROS client library.

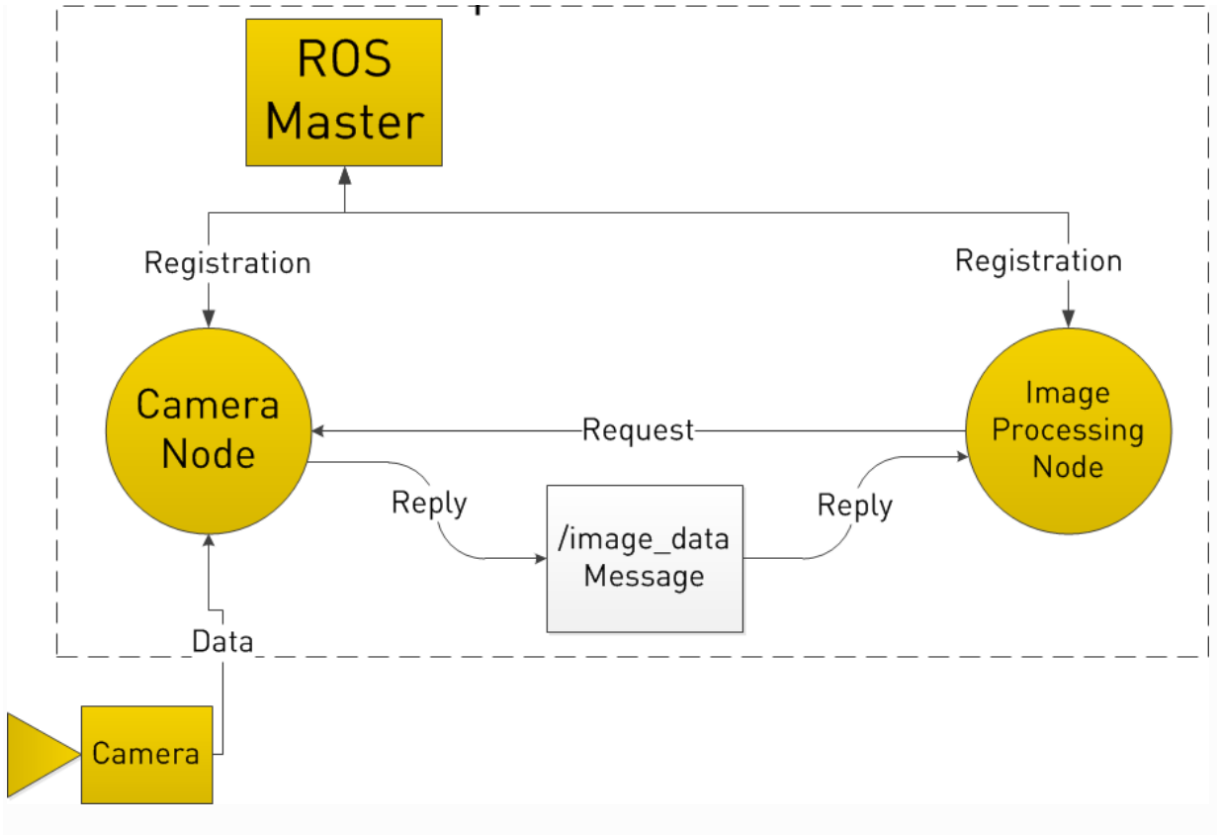
ROS Service

Difference between services and publishing and subscribing to topics



ROS Service

How does ROS service works?

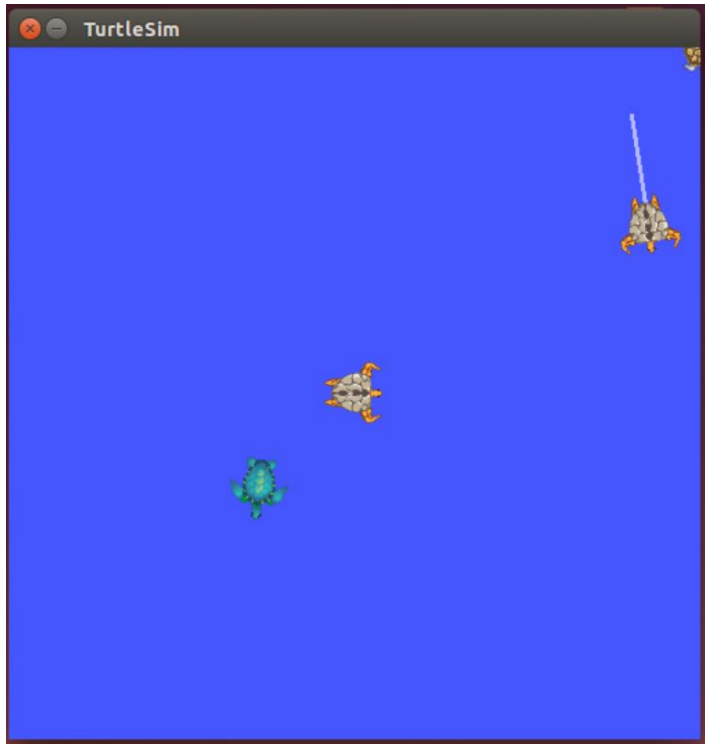


http://www.clearpathrobotics.com/assets/guides/ros/Intro%20to%20the%20Robot%20Operating%20System.html

rosservice command line tool

- $ rosservice **call** /service args: This tool will call the service using the given arguments
- $ rosservice **find** service_type: This command will find services in the given service type
- $ rosservice **info** /service: This will print information about the given service
- $ rosservice **list**: This command will list the active services running on the system
- $ rosservice **type** /service: This command will print the service type of a given service
- $ rosservice **uri** /service: This tool will print the service ROSRPC URI

Ros Service Example



`clear` (std_srvs/Empty)
Clears the turtlesim background and sets the color to the value of the background parameters.

`reset` (std_srvs/Empty)
Resets the turtlesim to the start configuration and sets the background color to the value of the background.

`kill` (turtlesim/Kill)
Kills a turtle by name.

`spawn` (turtlesim/Spawn)
Spawns a turtle at (x, y, theta) and returns the name of the turtle. Also will take name for argument but will fail if a duplicate name.

`turtleX/set_pen` (turtlesim/SetPen)
Sets the pen's color (r g b), width (width), and turns the pen on and off (off).

`turtleX/teleport_absolute` (turtlesim/TeleportAbsolute)
Teleports the turtleX to (x, y, theta).

`turtleX/teleport_relative` (turtlesim/TeleportRelative)
Teleports the turtleX a linear and angular distance from the turtles current position.

```
melih@melih-VirtualBox:~/catkin_ws$ rosservice call /spawn 10 10 10 melih
```

```
melih@melih-VirtualBox:~/catkin_ws$ rosservice call /turtle1/set_pen 10 10 10 30 0
```

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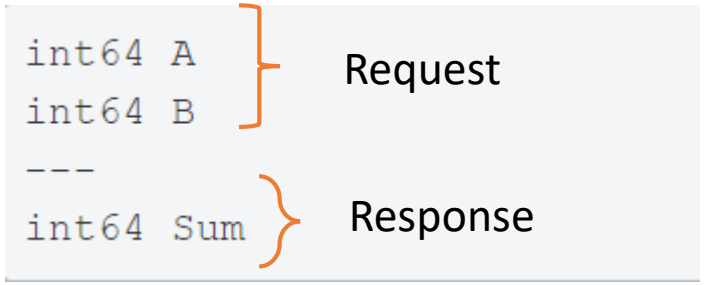
ROS srv

- srv: an srv file describes a service.
- It is composed of two parts: a request and a response.
- srv files are just like msg files, except they contain two parts: a request and a response. The two parts are separated by a '---' line. Here is an example of a srv file:



How to create ROS srv?

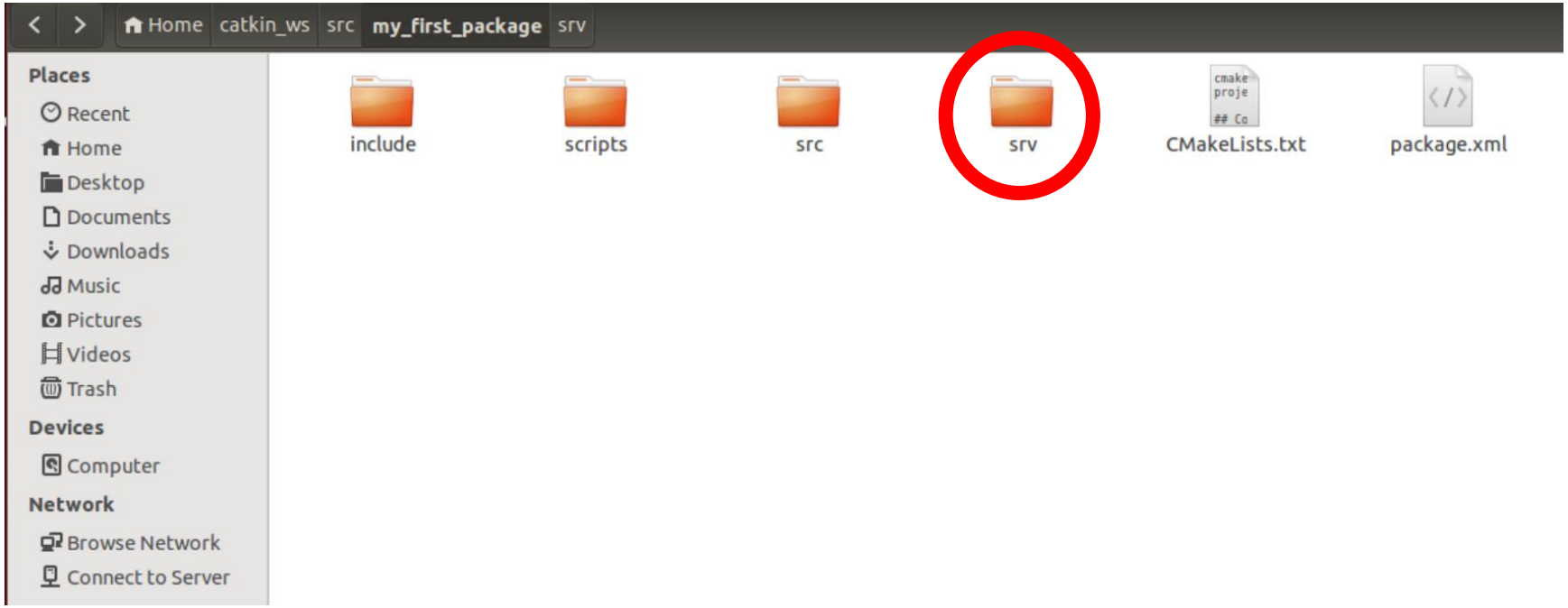
- Defining a Service
- Implement the Service
- Service Server
- Use the service
- Service Client

How to define a ROS srv?

- It is done in a service definition file
- It is .srv file
- It is just like message definition files. Maybe just a little bit more complicated.
- It has both input types and output types

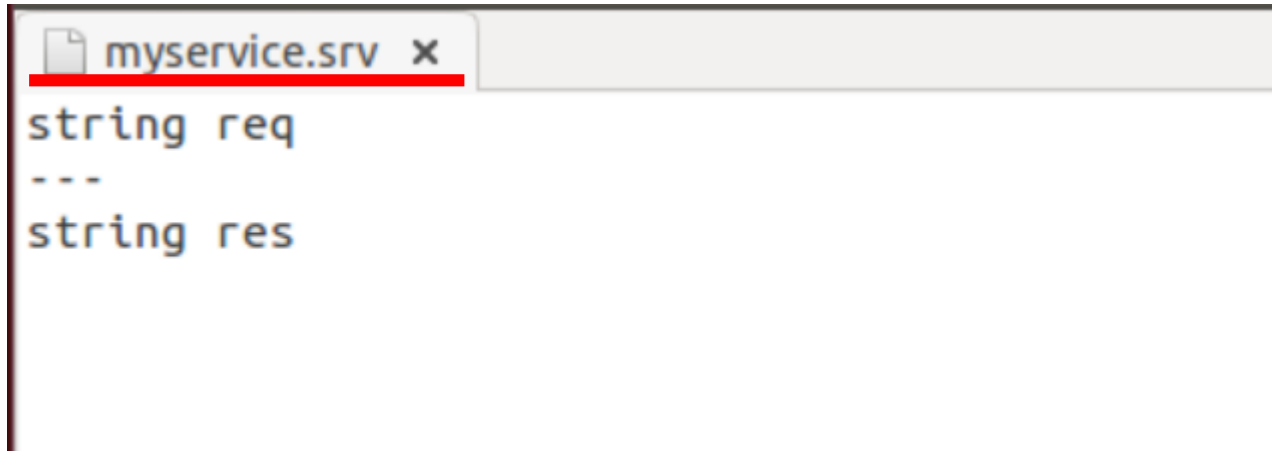
How to define a ROS srv?

- It is not a requirement, but traditionally these files are created in srv directory in the main package directory.



How to define a ROS srv?

- There are three dashes between input and output definitions.



How to create ROS srv?

- We need to run catkin_make to create the code and class definitions that we will actually use when interacting with services.
- In order to get catkin_make build this code, we need to modify some files.
  - **CMakeList.txt**
  - **Package.xml**

How to create ROS srv?

- We need to make sure massage generation package is included.

CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8.3)
project(my_first_package)

## Compile as C++11, supported in ROS Kinetic and newer
# add_compile_options(-std=c++11)

## Find catkin macros and libraries
## if COMPONENTS list like find_package(catkin REQUIRED COMPONENTS xyz)
## is used, also find other catkin packages
find_package(catkin REQUIRED COMPONENTS
  roscpp
  rospy
  std_msgs
  message_generation
)
```

How to create ROS srv?

- We need to tell catkin make which service definition files are going to be compiled.

CMakeLists.txt

```
##   * uncomment the add_*_files sections below as needed
##     and list every .msg/.srv/.action file to be processed
##   * uncomment the generate_messages entry below
##   * add every package in MSG_DEP_SET to generate_messages(DEPENDENCIES ...)

## Generate messages in the 'msg' folder
# add_message_files(
#   FILES
#   Message1.msg
#   Message2.msg
# )

## Generate services in the 'srv' folder
 add_service_files(
   FILES
   myservice.srv
 )
```

How to create ROS srv?

- We must make sure the dependencies for the service definition files is declared.

CMakeLists.txt

```
)

## Generate actions in the 'action' folder
# add_action_files(
#   FILES
#   Action1.action
#   Action2.action
# )

## Generate added messages and services with any dependencies listed here
 generate_messages(
   DEPENDENCIES
   std_msgs
 )
```

How to create ROS srv?

Our new dependencies on rospy and the message system are needed during build time and runtime.

package.xml

```
<!--   BSD, MIT, Boost Software License, GPLv2, GPLv3, LGPLv2.1, LGPLv3 -->
<license>TODO</license>


<!-- Url tags are optional, but multiple are allowed, one per tag -->
<!-- Optional attribute type can be: website, bugtracker, or repository -->
<!-- Example: -->
<!-- <url type="website">http://wiki.ros.org/my_first_package</url> -->


<!-- Author tags are optional, multiple are allowed, one per tag -->
<!-- Authors do not have to be maintainers, but could be -->
<!-- Example: -->
<!-- <author email="jane.doe@example.com">Jane Doe</author> -->


<!-- The *depend tags are used to specify dependencies -->
<!-- Dependencies can be catkin packages or system dependencies -->
<!-- Examples: -->
<!-- Use depend as a shortcut for packages that are both build and exec dependencies -->
<!--   <depend>roscpp</depend> -->
<!--   Note that this is equivalent to the following: -->
<!--   <build_depend>roscpp</build_depend> -->
<!--   <exec_depend>roscpp</exec_depend> -->
<!-- Use build_depend for packages you need at compile time: -->
<build_depend>message_generation</build_depend>
<!-- Use build_export_depend for packages you need in order to build against this package: -->
<!--   <build_export_depend>message_generation</build_export_depend> -->
<!-- Use buildtool_depend for build tool packages: -->
<!-- Use exec_depend for packages you need at runtime: -->
<exec_depend>message_runtime</exec_depend>
<!-- Use test_depend for packages you need only for testing: -->
<!--   <test_depend>gtest</test_depend> -->
```

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ROS Service Server

server.py

```
#!/usr/bin/env python

from my_first_package.srv import myservice
import rospy

def handle_service(data):
    a = str(data.req) + " 1234"
    return a

def add_numbers():
    rospy.init_node('service_server')
    s = rospy.Service('add_numbers_to_my_text', myservice, handle_service)
    rospy.spin()

if __name__ == "__main__":
    add_numbers()
```

ROS Service Test

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rossrv show myservice
[my_first_package/myservice]:
string req
---
string res
```

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rosservice list
/add_numbers_to_my_text
/rosout/get_loggers
/rosout/set_logger_level
/service_server/get_loggers
/service_server/set_logger_level
melih@melih-VirtualBox:~/catkin_ws$
```

ROS Service Server Test

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ROS Service Client

client.py

```
#!/usr/bin/env python

import rospy
from std_msgs.msg import String
from my_first_package.srv import *

#create a handle for calling the service
handle = rospy.ServiceProxy('add_numbers_to_my_text', myservice)

def callback(data):
    # call a service
    response = handle(data.data).res
    print(response)

def listener():
    rospy.init_node('test', anonymous=True)
    #blocks the node until the service is available
    rospy.wait_for_service('add_numbers_to_my_text')
    rospy.Subscriber('input', String, callback)
    rospy.spin()

if __name__ == '__main__':
    listener()
```

ROS Service Client

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rosrun my_first_package server.py
```

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rosrun my_first_package client.py
```

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rostopic pub -1 /input std_msgs/String melih
publishing and latching message for 3.0 seconds
```

```
melih@melih-VirtualBox: ~/catkin_ws
melih@melih-VirtualBox:~/catkin_ws$ rosrun my_first_package client.py
melih 1234
```

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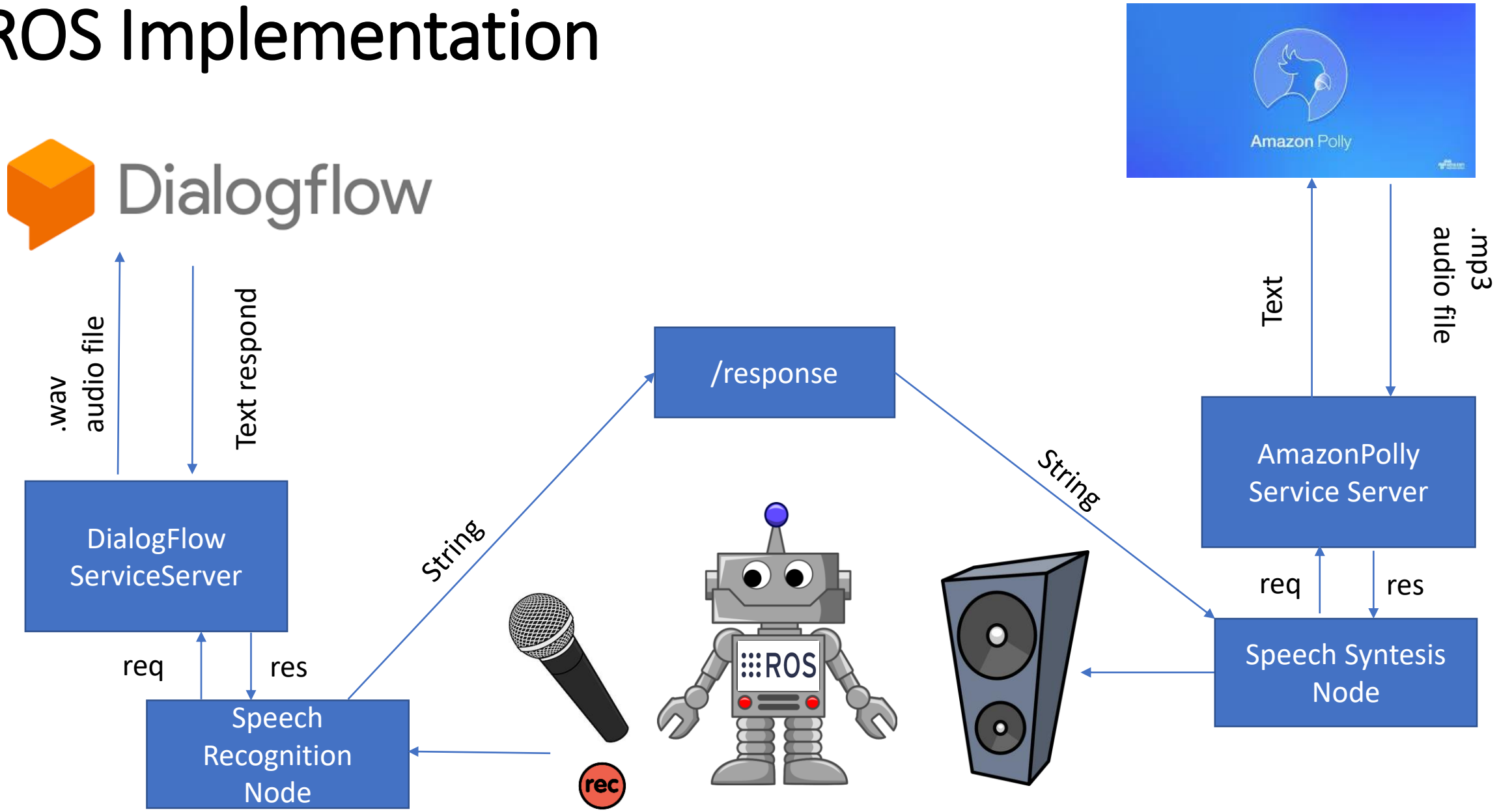
ROS Implementation



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Speech Recognition and Speech Synthesis

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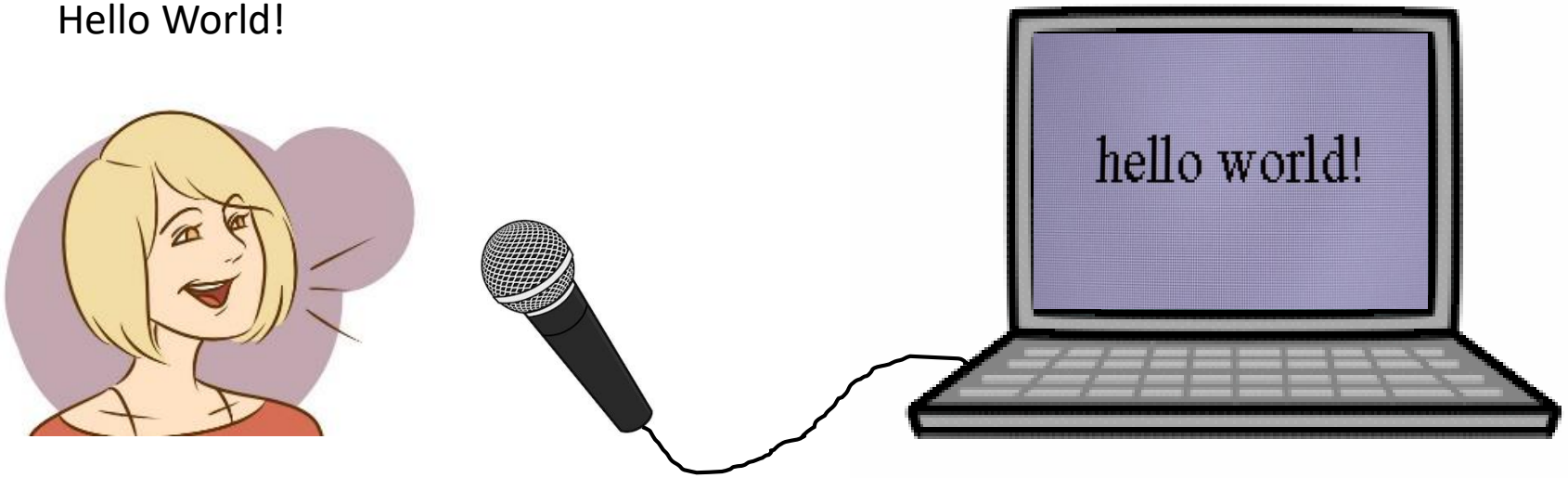
What is Speech Recognition?

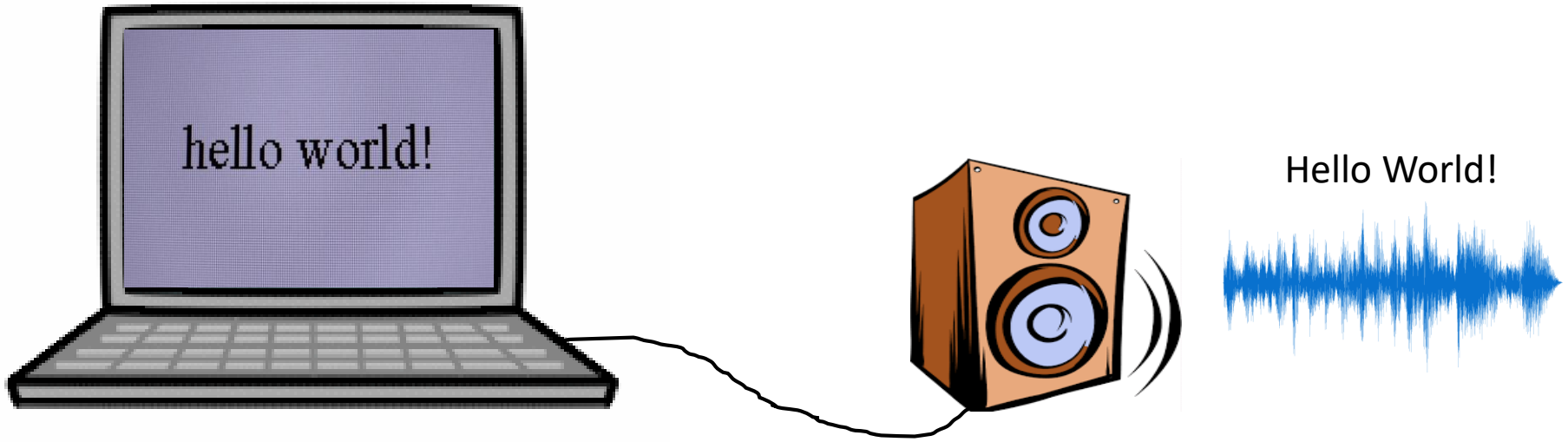
- The task of **speech recognition** is to convert speech into a sequence of words by a computer program

Hello World!



What is Speech Syntesis?

- **Speech synthesis** is artificial simulation of human speech which is created by a computer or other device.



Where are they used?

- Computers
- Telemarketing
- Smart Phones
- Emergencies
- Phone Call Routing
- Smart Homes
- Cars
- Robots
- Etc.

The Current State of Art in Speech Technologies

Speech Applications and Technologies

- Text
- Voice
- Ink etc..

Input Technologies

- Google Cloud Voice
- Dialogflow
- Amazon Polly

Apps

- Web Application
- Software
- Your Robot

Cloud Resources

Output Technologies

- Text
- Voice
- Ink etc..

Local Resources

- Espeak
- pocketsphinx

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Dialog Management

- Controlling the interchange of information between users and application
- Three dialog styles
  - **Human-directed** conversational dialogs
    - User asks a question or speaks a command and the computer responds.
  - **Application-directed** conversational dialogs
    - Application asks questions to get answers and instructions from a user.
  - **Mixed-initiative** dialogs
    - User and application take turns driving the conversations.

Three Dialog Styles

Application Directed

Robot: What month?

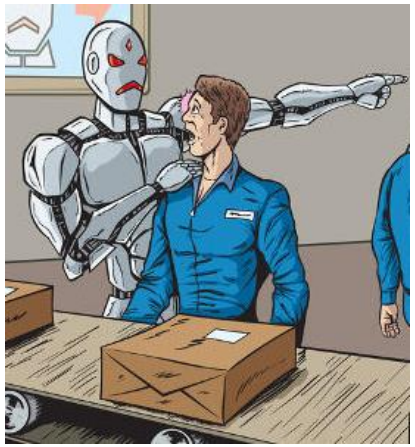
Human: February

Robot: What day of the week?

Human: Twelve

Robot: What year?

Human: Nineteen ninety-seven



Human Directed

Human: Set month to February

Robot: Month is February

Human: Set day to twelve

Robot: Day is twelve

Human: Set year to nineteen ninety-seven

Robot: Year is nineteen ninety-seven

Mixed initiative

Robot: What month?

Human: February twelve nineteen ninety-seven

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Speech Recognition

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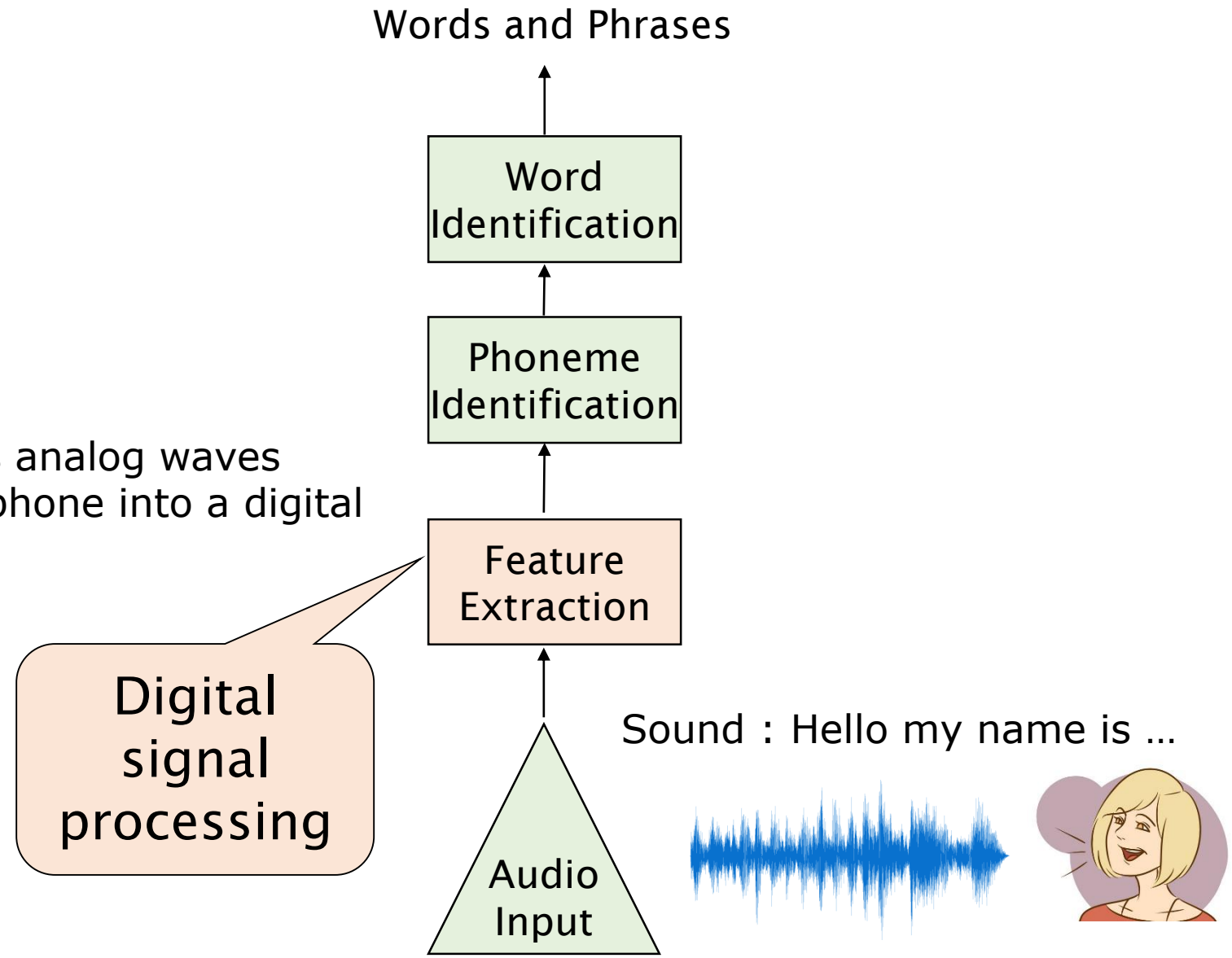
Speech Recognition

ASR – Automated Speech Recognition

- Advantages
  - User does not convert choices to a digit
- Disadvantages
  - Occasional failure to recognize what user said
    - Noise
    - Accent
    - Long Delay
  - Some times time-consuming dialogs
    - Users may interrupt prompts by “barge-in”

How Speech Recognition Works



- Computer converts analog waves spoken into a microphone into a digital format.
- Noise reduction

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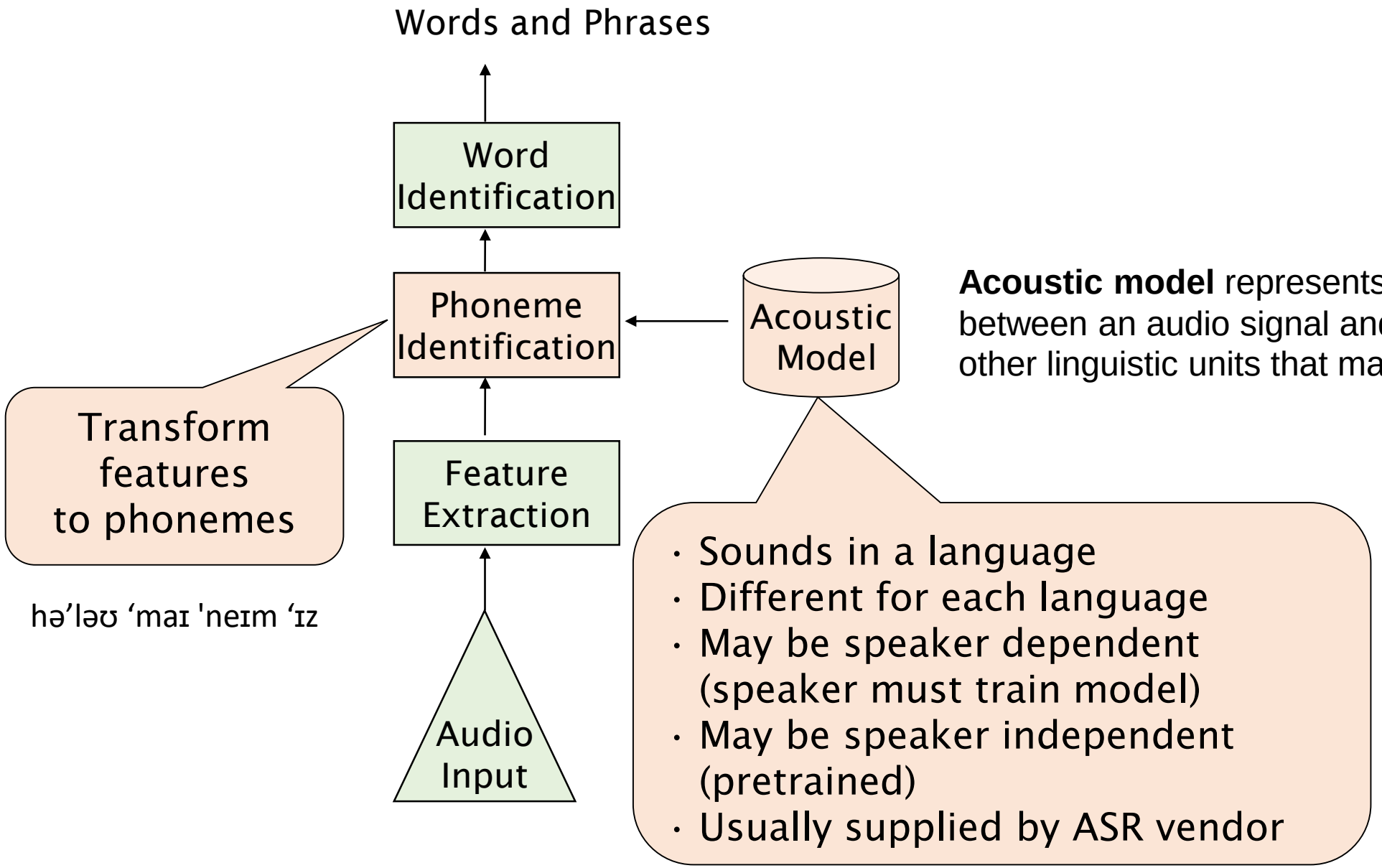
How Speech Recognition Works



Acoustic model represents the relationship between an audio signal and the phonemes or other linguistic units that make up speech.

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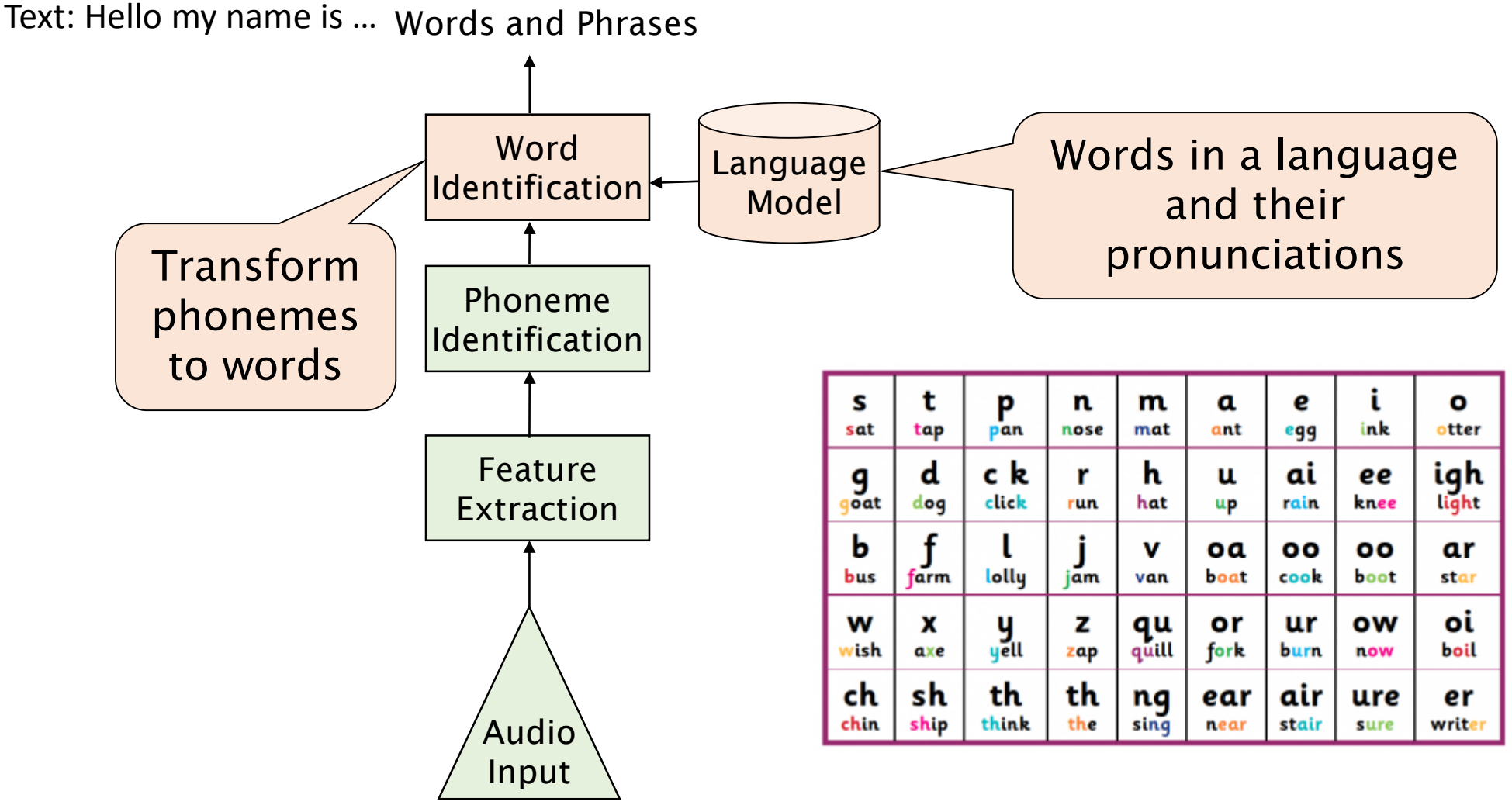
How Speech Recognition Works



s sat	t tap	p pan	n nose	m mat	a ant	e egg	i ink	o otter
g goat	d dog	c k click	r run	h hat	u up	ai rain	ee knee	igh light
b bus	f farm	l lolly	j jam	v van	oa boat	oo cook	oo boot	ar star
w wish	x axe	y yell	z zap	qu quill	or fork	ur burn	ow now	oi boil
ch chin	sh ship	th think	th the	ng sing	ear near	air stair	ure sure	er writer

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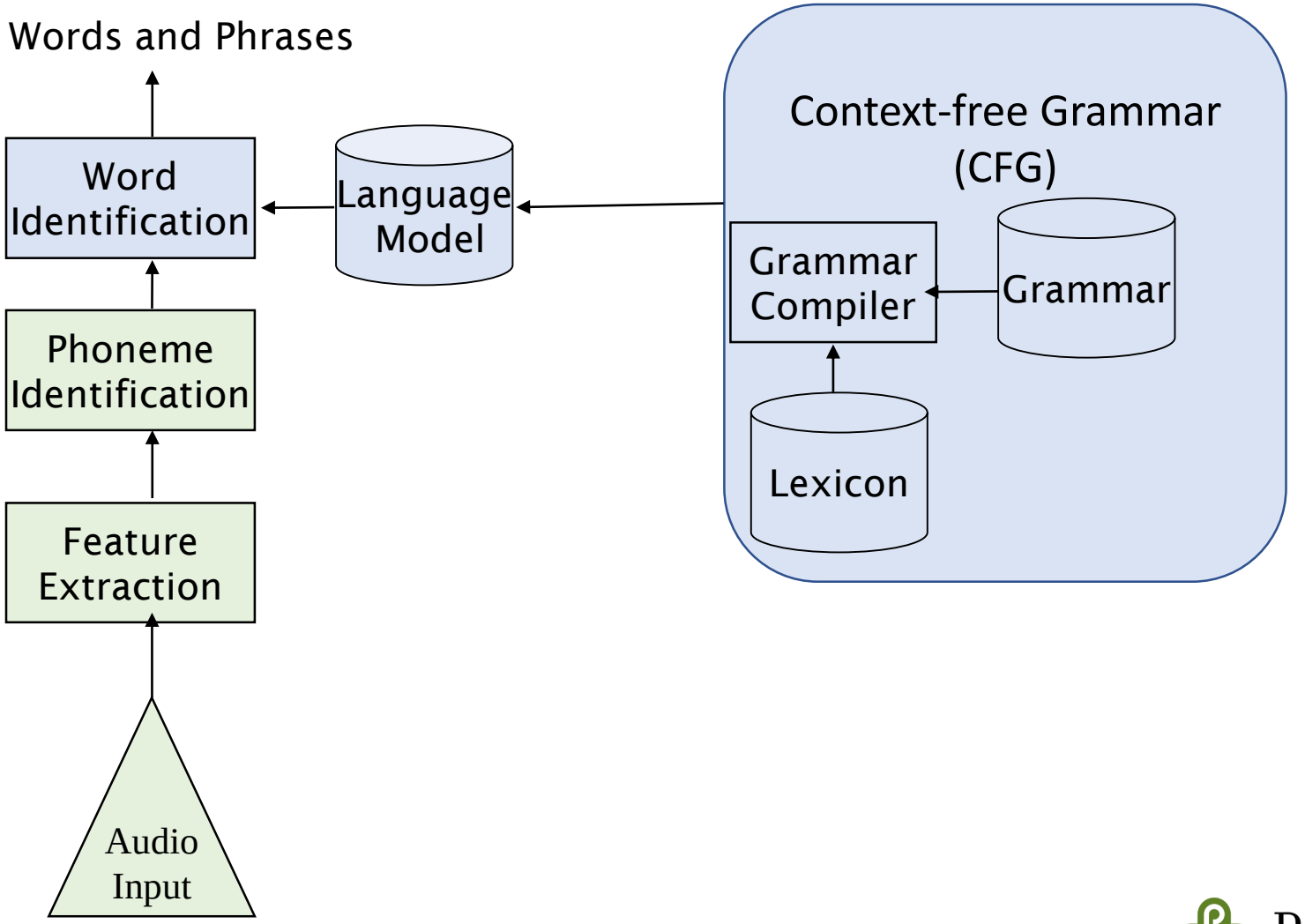
Speech Recognition

- There are two common methods
- Grammar-based
  - Developer specifies words to be recognized
- Statistical Language Models
  - Developer records and tags phrases

Grammar-based Speech Recognition



Where Are Grammars Used?

- Interactive Response Systems (IVR)
  - Automated telephone agents
- Each step may use a different grammar
  - Grammar defines only the words which the user may speak during a step
  - Application developers specify grammars for each step
- The same grammar may be reused in multiple applications

Grammar Rules Example

- In order to create rules XML format is used

```
<grammar
type = "application/grammar+xml"
root = "request"
mode = "voice">
    <rule id = "request">
        <ruleref uri = "#color"/>
        <ruleref uri = "#size"/>
    </rule>
```

```
<rule id = "color">
    <one-of>
        <item> red </item>
        <item> green </item>
        <item> blue </item>
    </one-of>
</rule>

<rule id = "size">
 <one-of>
        <item> small </item>
        <item> medium </item>
        <item> large </item>
    </one-of>
</rule>
```

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Statistical Language Model-based Recognition Technologies

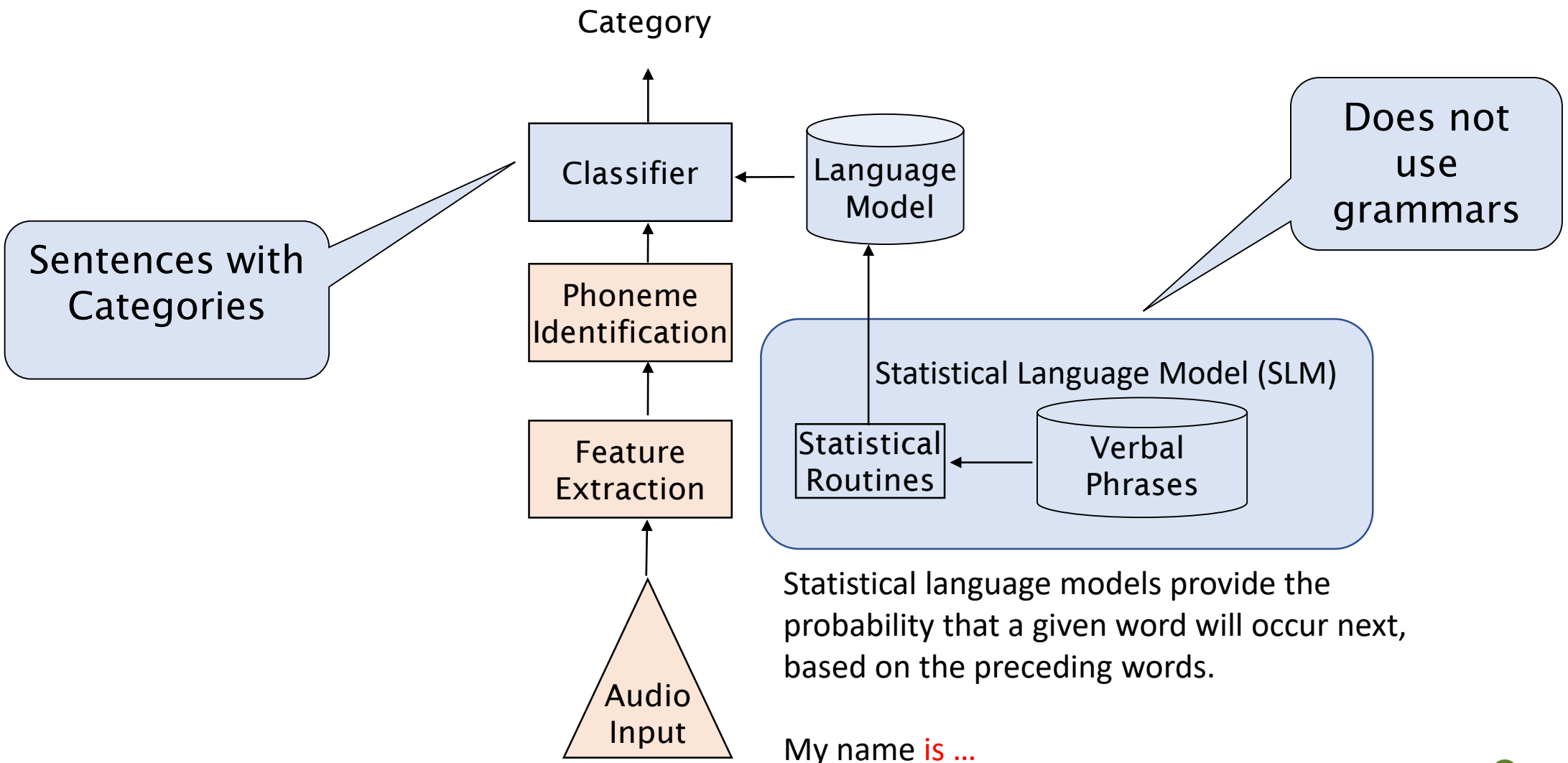
- Call Routing
- Speaker Identification
- Dictation
- Speaker emotion
- Voice pitch
- Age Detection
- Gender Detection
- Intoxication Detection
- Stress Detection
- Medical conditions (e.g., sleep apnea)

Example Verbal Phrases with Label

• “I have a problem with my bill”	accounting
• “Where is my order?”	shipping
• “My gadget arrived broken”	customer service
• “I need to return my gadget”	shipping
• “My statement is wrong”	accounting
• “I want a refund”	accounting

Label thousands of verbal phrases

Statistical Language Model-based Speech Recognition



Statistical language models provide the probability that a given word will occur next, based on the preceding words.

My name is …

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Grammars vs. Statistical Language Models

Statistical Language Models (SLMs)

- Data-driven
- High-accuracy
- Complex to assemble
- Natural language
- Used for dictation

Context-Free Grammars (CFGs)

- Hand-crafted rules
- Very high-accuracy
- Easy to assemble
- Finite phrases
- Used for
  - Interactive Voice Response (IVR)
  - Command and Control

Usage of Statistical Language Model-based Recognition Technologies

- Widely available
  - Call routing
  - Speaker authentication
  - Dictation
- Actively being researched
  - Speaker emotion
  - Voice Pitch
  - Age Detection
  - Gender Detection
  - Intoxication Detection
  - Stress Detection
  - Medical conditions (e.g., sleep apnea)

Speech Syntesis

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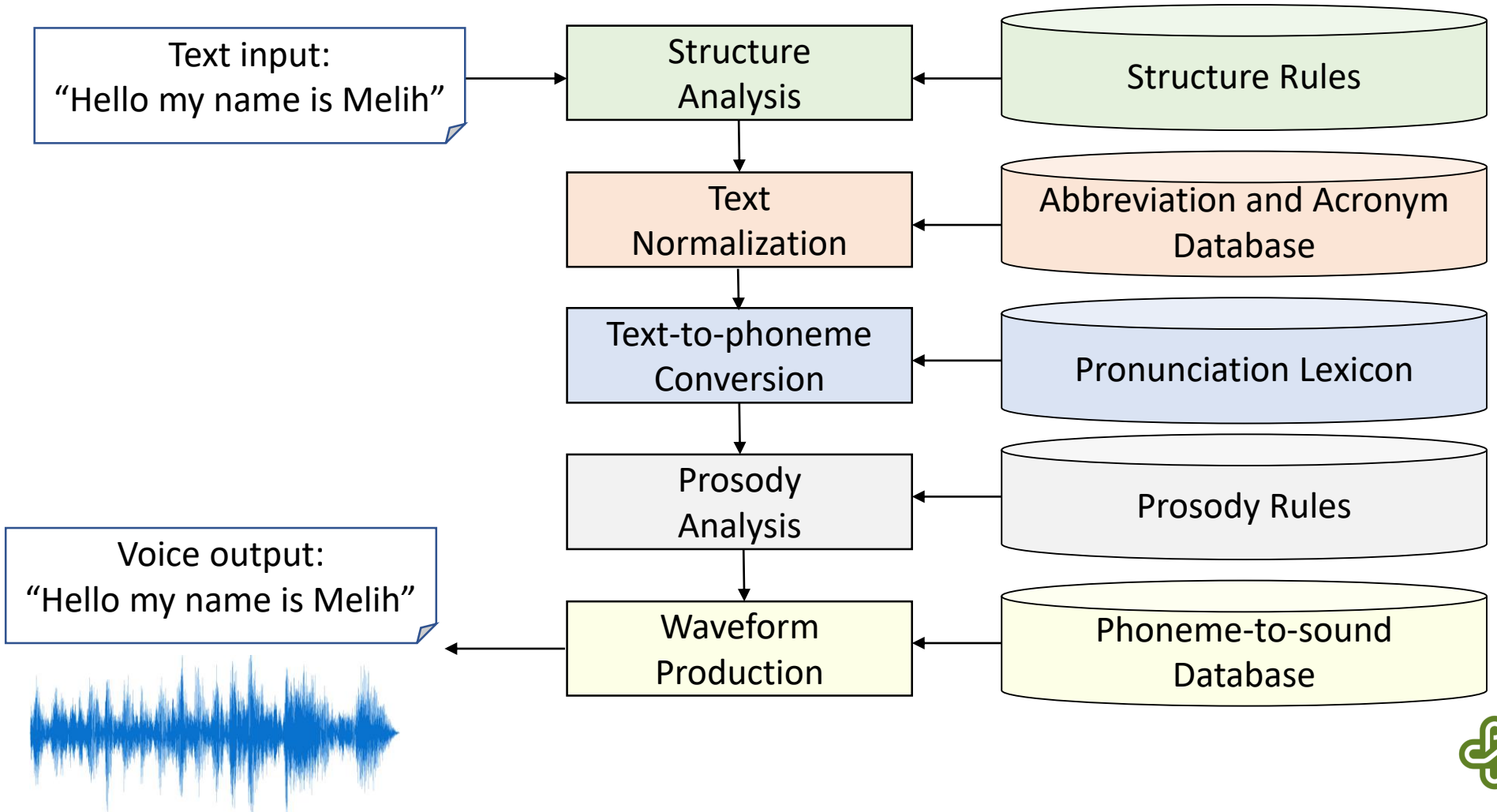
Speech Synthesis
(Text-To-Speech, TTS)



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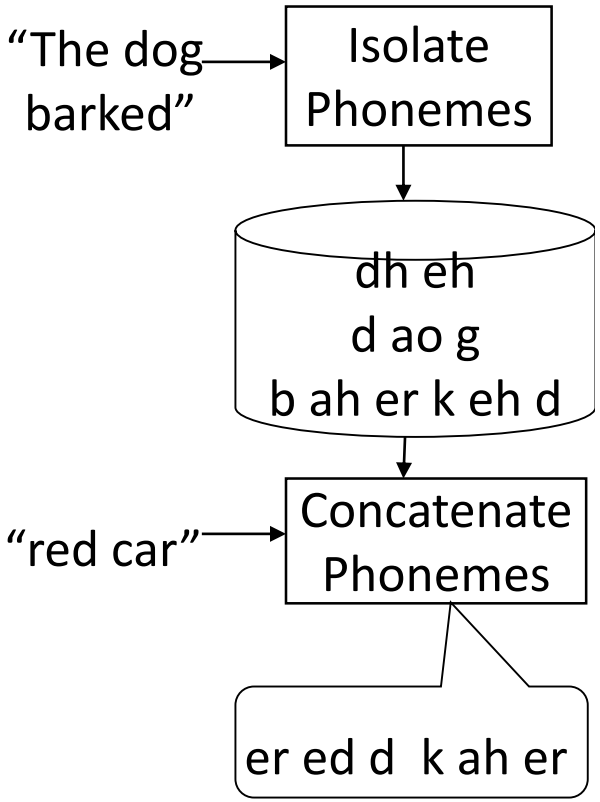
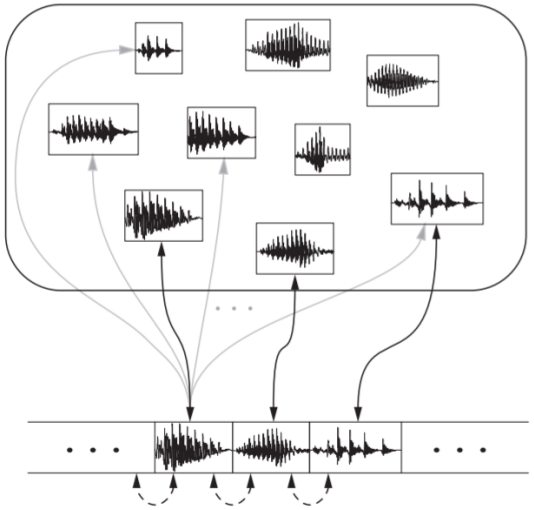
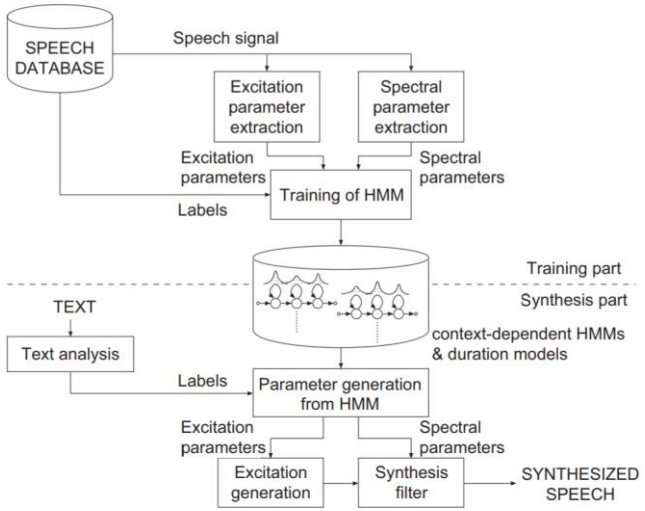
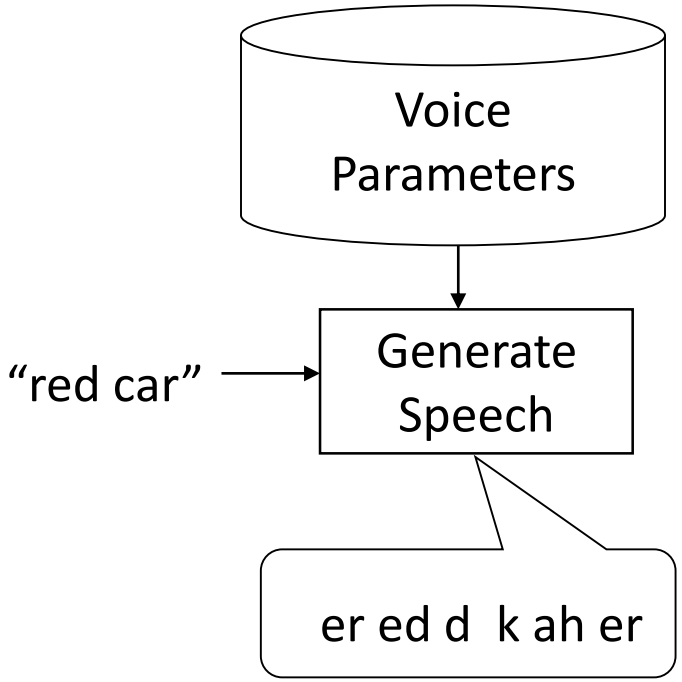
Concatenated vs. Parameter-based Speech Synthesis









Concatenative synthesis is a technique for synthesizing sounds by concatenating short samples of recorded sound (called *units*).
Need a professional speaker 2-10 hr.

Parametric synthesis model describes the speech using parameters, rather than stored exemplars.
It is statistical because it describes those parameters using statistics

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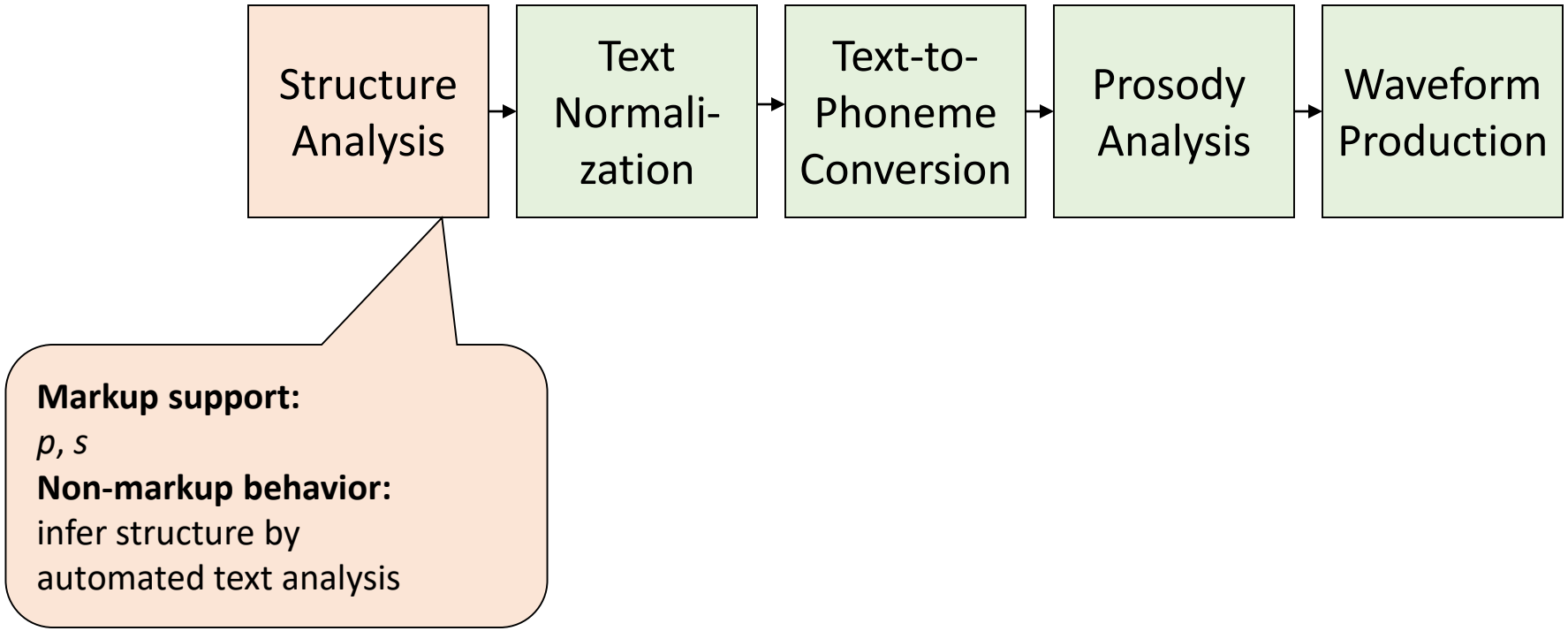
Speech Synthesis Markup Language (SSML)



Dr. Smith lives at 214 Elm Dr. He weights 214 lb. He plays bass guitar. He also likes to fish; last week he caught a 19 lb. bass.

Before and after Structure Analysis

- Before structure analysis
  - Dr. Smith lives at 214 Elm Dr. He weights 214 lb. He plays bass guitar. He also likes to fish; last week he caught a 19 lb. bass.
- After structure analysis

```
<p>
  <s>
    Dr. Smith lives at 214 Elm Dr.
  </s>
  <s>
    He weights 214 lb.
  </s>
<s>
    He plays bass guitar.
  </s>
  <s>
    He also likes to fish; last week he caught
     a 19 lb. bass.
  </s>
</p>
```

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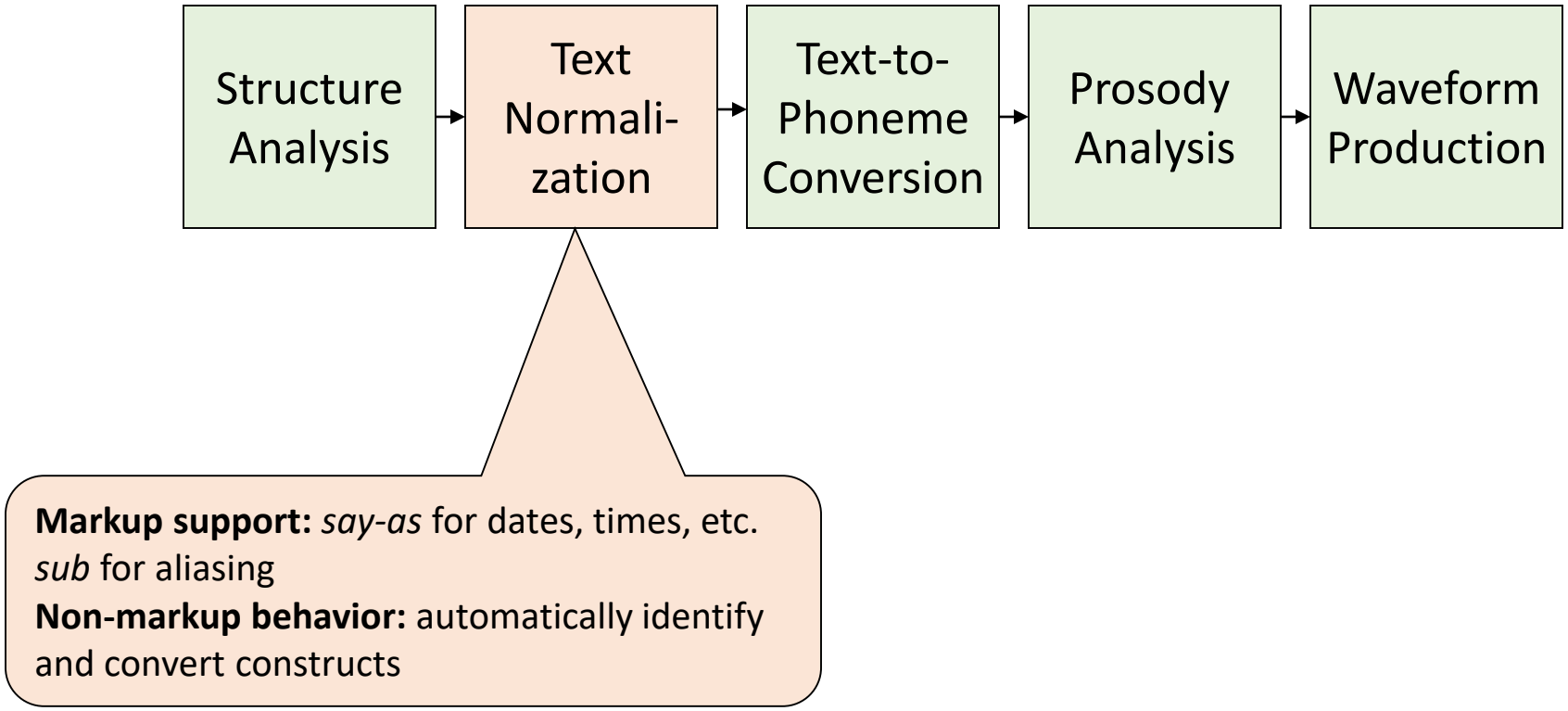
Speech Synthesis Markup Language

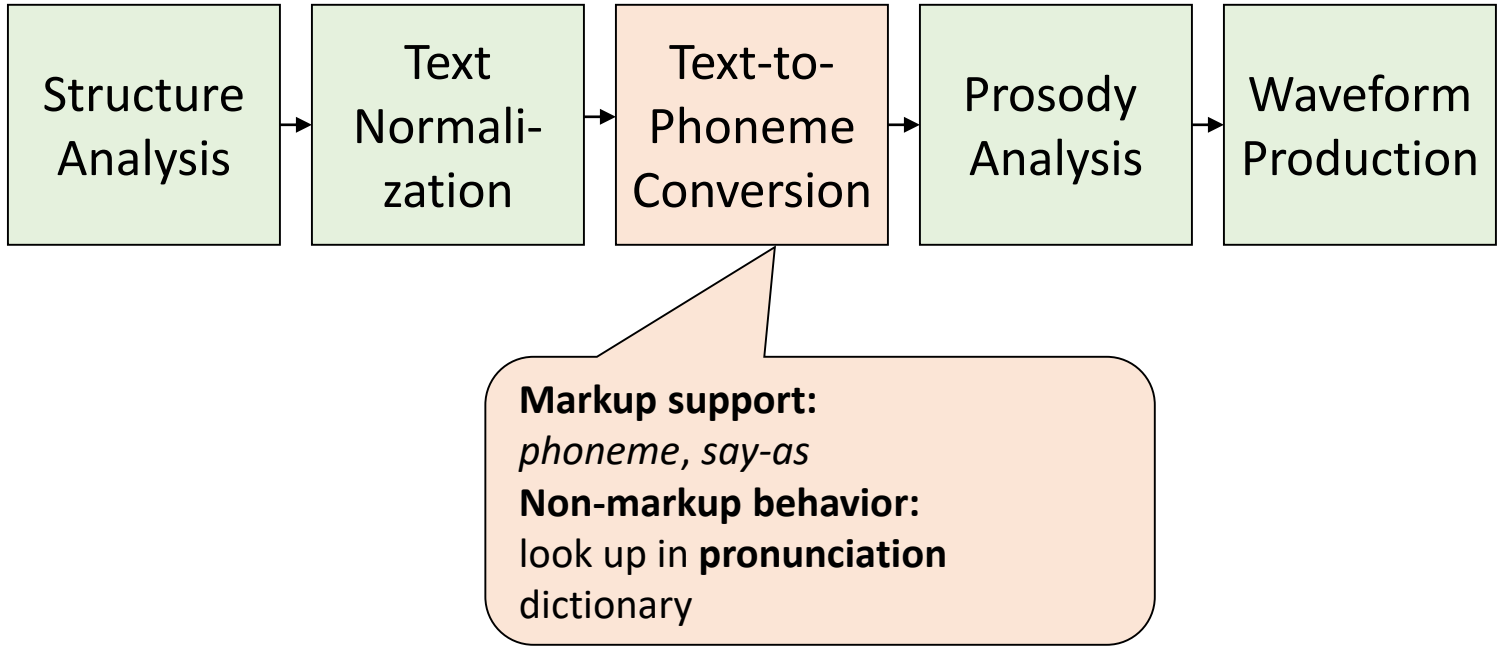


He weights 214 **_{** lb**.}**

After Text Normalization

  <s>
    _{**Dr. **} Smith lives at 214 Elm **_{**Dr. **}**
  </s>
  <s>
    He weights 214 **_{** lb**.}**
  </s>
  <s>
    He plays bass guitar.
  </s>
  <s>
    He also likes to fish; last week he caught a 19 **_{** lb. **}** bass.
  </s>

Speech Synthesis Markup Language



He plays **<phoneme alphabet = "ipa" ph="beɪs">**bass**</phoneme>** guitar.

Text-to-Phoneme Conversion

```
<p>
  <s>
    <sub alias = "doctor">Dr.</sub> Smith lives
    at <say-as interpret-as = “address"> 214 </sayas> Elm
    <sub alias = "drive">Dr. </sub>
  </s>
  <s>
    He weighs <sayas interpret-as = "number">214 </sayas>
    <sub alias= "pounds"> lb.</sub>
  </s>
  <s>
    He plays <phoneme alphabet = "ipa" ph="beɪs">bass</phoneme> guitar.
  </s>
  <s>
    He also likes to fish; last week he caught a
    <sayas interpret-as= "number">19 </sayas>
    <sub alias= "pound"> lb. </sub>
    <phoneme alphabet = "ipa" ph="bæs">bass</phoneme>.
  </s>
</p>
```

Bass guitar

Bass fish

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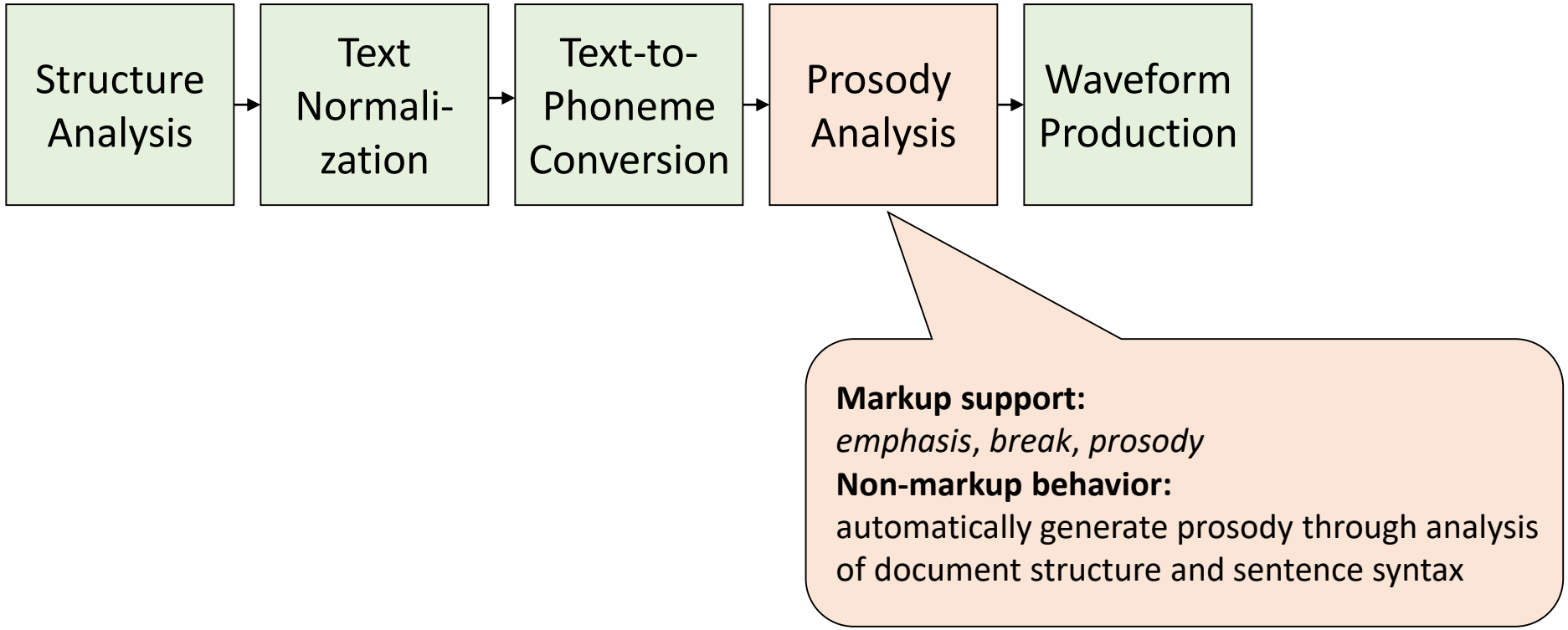
Speech Synthesis Markup Language



Prosody Analysis

```
<prompt>
   Environmental control menu. Do you want to adjust the lighting or temperature?
</prompt>
```

```
<prompt>
  Environmental control menu
  <break/>  <emphasis level = "reduced" >
  do you want to adjust the </emphasis>
  <emphasis level = "strong">
  lighting </emphasis>
  <break/>
   or <emphasis level = "strong">
   temperature? </emphasis>
</prompt>
```

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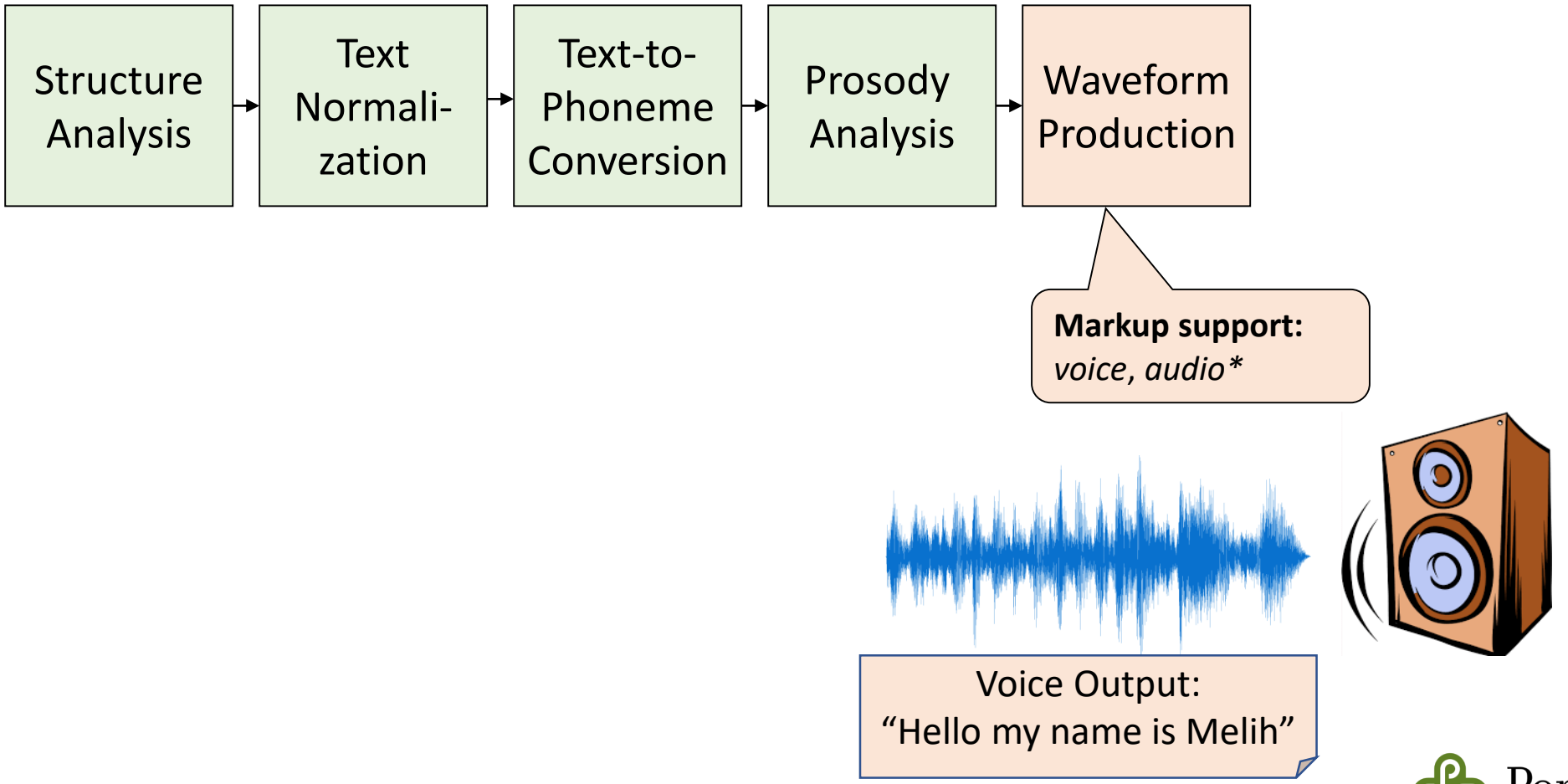
Speech Synthesis Markup Language



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Prerecorded messages vs. Speech Synthesis

Prerecorded messages

- Natural sounding
- Easy to understand
- Static data
- Tedious to record and tag

Speech Synthesis (TTS)

- Artificial sounding (Getting better)
- May be difficult to understand
- Computer-generated data
- Easy to specify

Prerecorded Messages vs. Speech Synthesis

Prerecorded Messages

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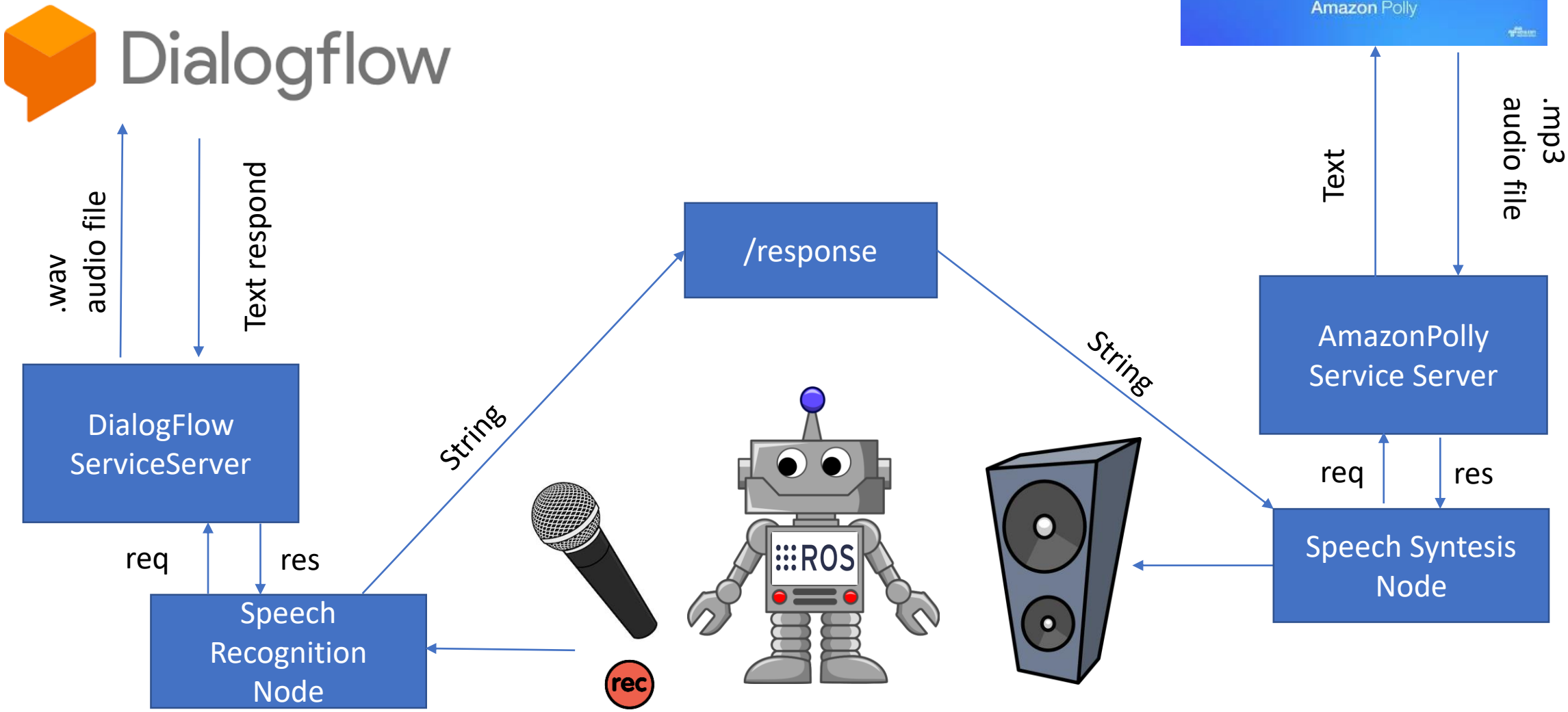
Speech Structure Overview



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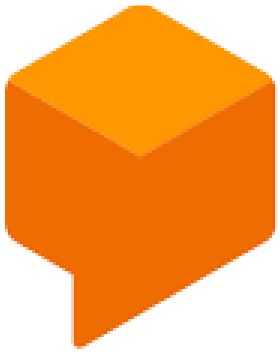

Dialogflow

Google Dialogflow

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Introduction to Dialogflow

- DialogFlow is a natural processing tool.
- Started as API.AI in 2010, acquired by Google
- Can be used to create user voice interfaces and chatbots

Introduction to Dialogflow

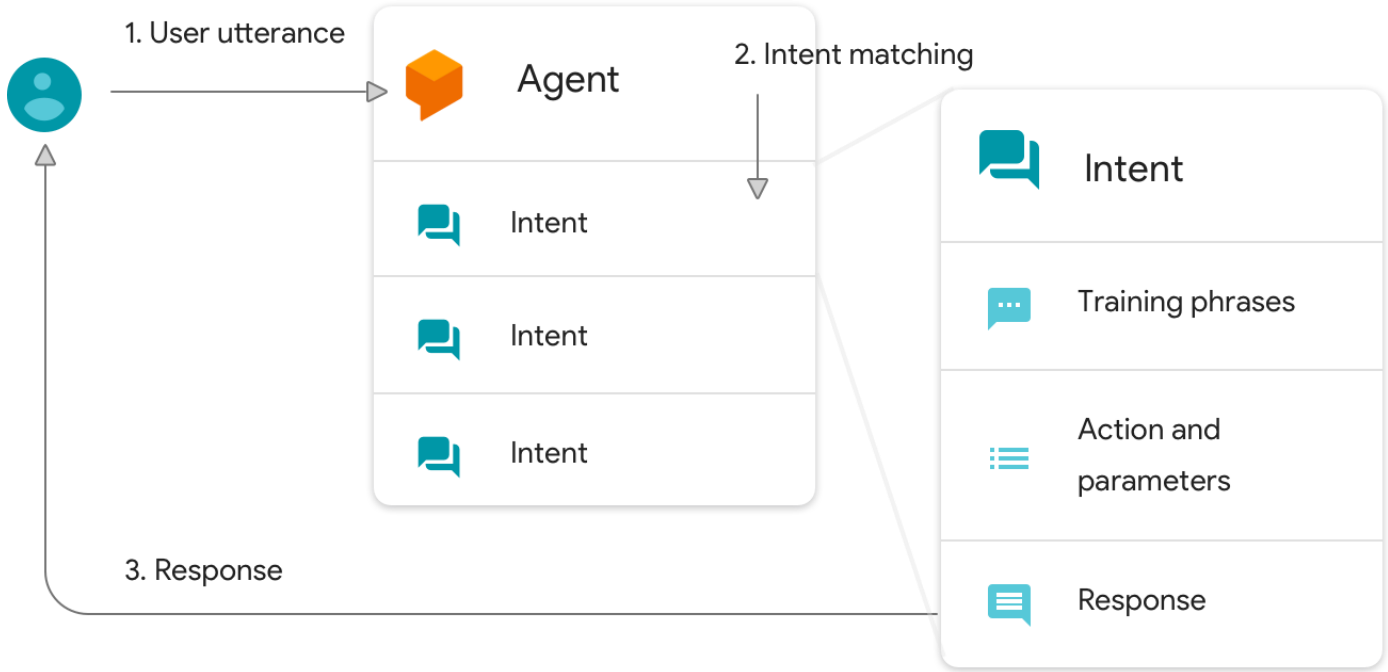
- You create a decision tree
- And Dialogflow uses Machine Learning to match user inputs to given training examples to figure out what the user's intent.
- It is flexible
- It keeps learning
- It works in many different circumstances
- It an be used with many programming languages such as Python, Java, Go, PHP, Ruby etc

Main Concepts and Features of Dialogflow

- Agent
  - Prebuild Agents
- Intents
  - Action and Parameters
  - Context
  - Events
  - Responses
  - Contexts
- Entities
  - System Entities
  - Custom Entities
- Training
- Small Talk

Agents

- Antural Language Understanding (NLU) modules.
- It can be included in your app, website, product or services
- It translates text and spoken user requests into actionable data.



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Intents

- Represents a mapping between what a user says and what action should be taken by your software
- In order to define how conversations work, **intents** are used in agent
- It maps user input to responses
- In each intent,
  - There are defined examples of user utterances that can trigger the intent
  - What to extract from the utterance
  - and how to respond.

Intents

- Intent has the following sections:
  - **User input (Text-Voice)**
    - Written in natural language and annotated with parameter values
    - “Weather forecast in Portland tomorrow”
  - **Action**
    - Steps your application will take when a specific intent has been triggered.
  - **Response**
    - Text, image, card, quick reply, custom payload
  - **Context**
    - Current context of a user's request
    - Resolves “it” or “them”

Entities

- Mechanism for identifying and extracting useful data from natural language inputs.
- Three entity types:
  - System Entity Types - defined by Dialogflow
  - Developer Entity Types - defined by developer
  - User - built for each individual end-user in every request
- Entities can be exported and downloaded

Entities - System Entity

- System Entity Type are defined by Dialogflow
  - **@sys.date** matches common date references such as "January 1, 2015" or "The first of January of 2015" and returns a reference value in ISO-8601 format: 2015-01-01T12:00:00-03:00.
  - **@sys.color** matches most popular colors and returns the matched color.
  - **@sys.unit-currency** matches amounts of money with indication of currency name, e.g., "50 euros" or "twenty dollars and five cents

Entities - Developer Entity

- Developer entity types are defined by developer
- For example, a brand might create an entity type to recognize its unique set of product names.
    - **@coffee**
    - **@tea**
    - **@bread**
    - **@condiments**
    - **@meats**

Entities

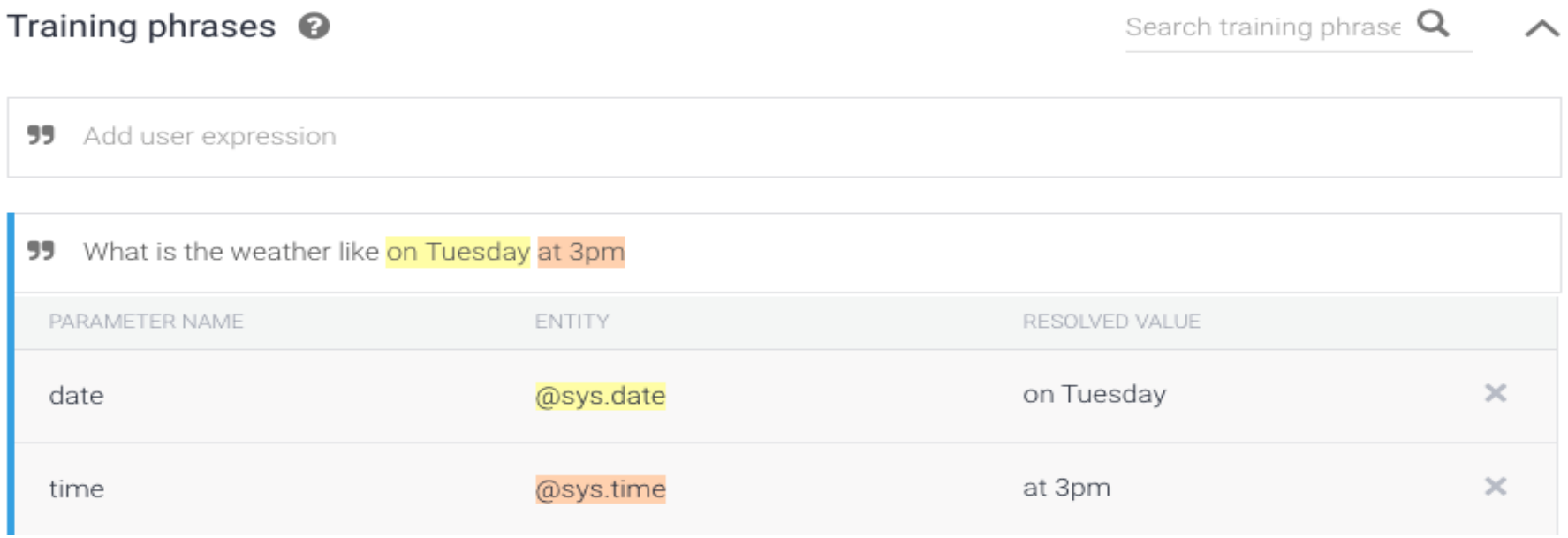
- User --built for each individual end-user in every request
  - Session entities extend or replace a developer entity at the user session level.
  - A user's session is the conversation they have with your agent from start to finish.
  - For example, if your agent has a @pets entity that includes "dog" and "cat", that entity could be updated to include "bird" or "fish" depending on the information your agent collects from a user.
    - **@pets**
      - **Dog**
      - **Cat**
      - **Bird**
      - **Fish**

Parameters

- Parameters are elements generally used to connect words in a user's response to entities.
- A corresponding parameter stores the extracted value from the utterance
- This lets us convert user input into structured data that we can use to do some logic or generate responses.

Parameters

- As an example, let's look at one of the example training phrases we defined earlier
- *User input/intent: "What is the weather like on Tuesday at 3pm".*
- The date and time entities (corresponding to the values *Tuesday* and *3 PM*) are automatically annotated as **@sys.date and @sys.time**



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Actions

- Step your application will take when a specific intent has been triggered by a user’s input.
- Actions can have parameters for extracting information from user requests

Responses

- Every intent must define a response that's returned to the user.
- There are two primary ways you can return a response to the user - either with a pre-defined, static response or with a response generated from a webhook.
- In both of these cases, you can use extracted parameters in the response.

Messages

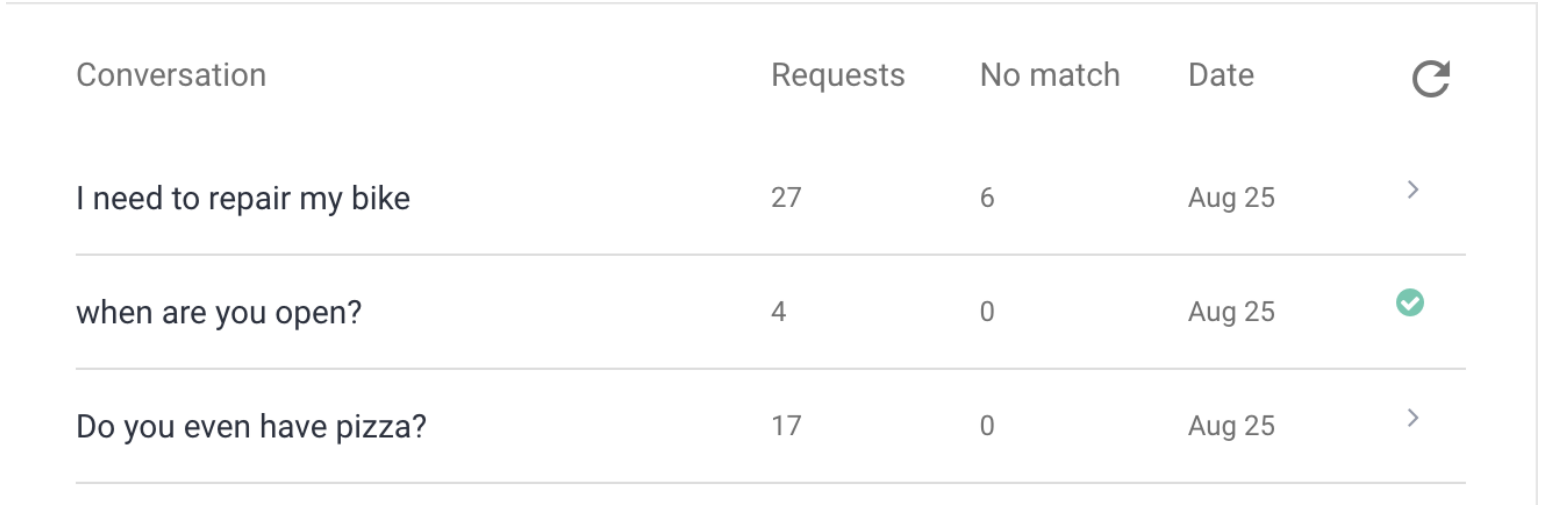
- Text
- Image
- Card
  - Consist of an image, a card title, a card subtitle, and interactive buttons
- Quick reply
  - Displayed as clickable buttons with pre-defined user responses.
- Custom payload
  - You can send custom payloads in the JSON format provided in the platforms documentation.

Events

- Events allow you to invoke intents based on something that has happened instead of what a user communicates.

Training

- Dialogflow is a natural language processing tool that is based on machine learning
- That means you can add training data that the agent learns from and uses to improve its performance.
- Logs of user interactions can be used to improve the performance of Dialogflow agents.



Conversation	Requests	No match	Date
I need to repair my bike	27	6	Aug 25
when are you open?	4	0	Aug 25
Do you even have pizza?	17	0	Aug 25

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Training

- Since Dialogflow's natural language processing is based on machine learning, you can add training data that the agent learns from and uses to improve its performance.
- Dialogflow's training feature provides an interface for incorporating both external and internal customer interaction logs into an agent's training phrases. You can use this feature to build a new Dialogflow agent using logs of existing customer interactions and to improve the performance of a live Dialogflow agent using its own logs.

Pre-build agents and Small Talk

- Dialogflow provides two out-of-the-box features that help get you started with agent and conversation design:
- **Prebuilt Agents**
  - Prebuilt Agents include intents and entities that cover the agent's topic.
  - You need to provide responses since they may depend on particular use cases or need to be retrieved from external sources (webhook or third-party API).
- **Small Talk**
  - Small Talk is used to provide responses to casual conversation.
  - This feature can greatly improve the user experience by covering common questions that may not pertain to your agent's intents you built.

Reference

- Portland State University
- Computer Science Department
- Spoken Language Interfaces - CS 410/510
- Instructor: Jim Larson
- Some slides from his lectures are updated and used in this documentation

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End of class

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