Spoken Dialogue Systems for Medication Management

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Abstract

Spoken dialogue systems have been rapidly growing in interest in the last few years, including in the field of health care. There is a growing need for automated systems that can do more than simply interviewing patients about their current health and medications using natural language. A well-crafted dialogue system with state management can allow tailored messages based on the inferred goals and beliefs of the user in the present moment. In this project, we explore the use of a custom statistical dialogue system created to provide drug product and prescription information to its users.

Introduction

One of the hallmarks of the voice-enabled commercial technologies is the virtual assistant, capable of performing complex tasks for its users with voice commands. This provides a new opportunity for advances in healthcare technology.

The number of senior citizens in the United States is expected to nearly double by 2050 (Ortman et al. 2014), which will place a significant additional burden on the already overburdened healthcare system. Voice assistant technology can provide tools that can help the aging population with performing health-related tasks and gathering health-related information that do not require supervision from healthcare professionals, especially for those individuals experiencing decline with their visual or motor skills.

For example, one of the key everyday tasks that patients need to perform outside of the doctor's office is to manage their medications and ensure adherence to the medication regimen. This is a task that lends itself well to automation with voice assistant technology but requires that the dialogue management system is aware of a large number of medications as well as additional information such as available dosages and formulations, routes of administration, interactions with other drugs and side-effects.

The long-term objective of our work is to develop an adaptable dialogue system which would be capable of interfacing with a range of available devices and other existing technologies on an as-needed basis.

Limitations of Commercial Dialogue Systems

Recent progress in natural language processing has allowed commercial dialogue systems to soar in popularity. While these systems work well for simple tasks, they are currently limited in two important aspects - contextual awareness and topic tracking. They do not recognize linguistic context (e.g. changes in conversation topic) while executing a particular task, forcing users into a structured conversation that may not match a natural flow of conversation. Most commercial dialogue systems, namely Google Home and Amazon Alexa, offer only a single-domain language model. While this generally works for simple workflows, a dialogue system capable of switching between multiple distinct domains can jump between multiple workflows associated with each domain. Furthermore, associating an interaction with a specific domain will increase the likelihood that a dialogue system will execute the correct task, as tasks requested during one domain of conversation may be rarely requested in another (Möller, Gödde, and Wolters 2008).

Application

The practical application of this pilot project is to improve medication adherence. Adhering to complex medication regimens with multiple potentially interacting medications to treat multiple disorders is difficult but non-adherence has serious implications for physical and mental well-being. Improved adherence can be facilitated by reminders given by the conversational assistant, but the value of reminders depends on context (e.g., stress may lead to forgetting), and reminders need to address both the case when the user forgets to take a medication and the case when the user takes medications repeatedly (Ihle et al. 2017).

In the context of using a conversational agent for improving adherence to medications, there are two key types of information for each medication to consider: drug product information, and prescription information. Drug product information (e.g., Prinivil 10mg oral tablet) is specific to the medication itself and can be automatically obtained from databases containing manufacturing data. Prescription information (e.g., take twice a day with meals) on the other hand is defined by the healthcare provider, and is specific to the patient. The latter can be obtained directly from the electronic health records or pharmacy systems; however, directly interfacing with clinical systems is subject to pro-

tected health information constraints and there is variability in how individual patients implement their doctors' recommendations and treatment plans in their everyday lives. Our proposed solution is to create a conversational agent capable of eliciting the details of individual use of medications and aiding patients and caregivers with tasks such as medication reconciliation or encouraging medication adherence. Our initial pilot application of this project uses a spoken dialogue system to elicit a record of current drug and prescription information directly from the patient.

PyDial

PyDial (Ultes et al. 2017) is a multi-domain statistical spoken dialog system toolkit that provides a framework for building a modular dialogue system. Each module in the dialogue system has pre-implemented statistical approaches to process data. The main focus of PyDial is to perform task-oriented dialogue, in which a user can search for an entity in a domain that matches some number of constraints.

PyDial provides modules for input processing (speech recognition and semantic decoding), dialogue management (belief tracking and policy management), and output processing (language generation and speech synthesis). All modules are capable of processing dialogue spanning multiple domains of conversation. PyDial's domain-related functionality is independent from its dialogue modules, thus the same modules can be used across multiple domains.

ULMS RxNorm API

RxNorm (Liu et al. 2005), created and managed by the U.S. Library of Medicine (ULMS), provides normalized names for clinical drugs. RxNorm was designed to allow different computer systems to communicate drug-related information effectively and unambiguously. Each medication variant is assigned a unique identifier, called a RxCUI, that differentiates between other variants of the same medication. The scope of this database includes all available prescription and over-the-counter medications available in the United States, including the generic and branded versions of clinical drugs.

The API behind RxNorm was chosen as the foundation of the ontology behind the dialogue system due to its regulated, high-quality information on medications. Ensuring that the dialogue system knows the exact medication patients are on will also aid the caregivers' role in managing their medication history.

Implementation

We created a medication ontology that was based off the RxNorm dataset with PyDial as the framework of the dialogue system. A sample patient record was created using a small subset of RxNorm data to test the effectiveness of the system. Handcrafted rules for natural language generation and understanding were created to match information inquiries for the patient record. A ReSpeaker kit, which is a microphone and speaker expansion board for Raspberry Pis, served as a speech client for the application. This dialogue system was capable of understanding and generating suitable responses to user input.

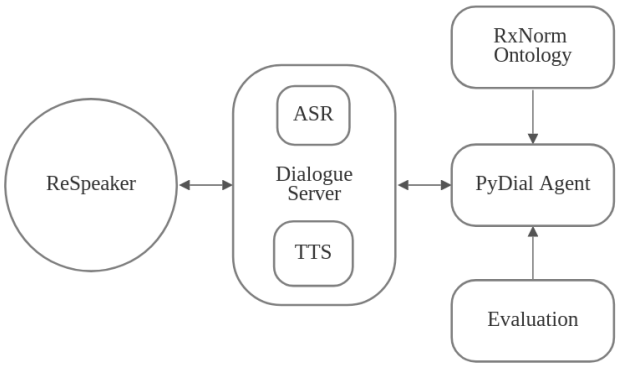

Figure 1: The architecture of the pilot application. The ReSpeaker hardware acts as a speech client that the dialogue server can receive natural language as input and output. Text is sent and received from the dialogue system.

Future Work

We will explore the use of PyDial's built-in language understanding module that uses support vector machines to classify input onto a set of semantic concepts. We will also explore the use of recurrent neural networks and/or long short term memory networks for the natural language generation component of PyDial. This approach can generate natural language from previous dialogue acts, allowing a greater variability of responses from the dialogue system while also taking linguistic context into consideration. It will also be important to develop an interface between PyDial and the APIs of multiple medical vocabularies such as RxNorm in order to leverage their extensive resources for information on side effects and drug-drug interactions.

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