Mixed-initiative Personal Assistants

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ABSTRACT

Specification and implementation of flexible human-computer dialogs is challenging because of the complexity involved in rendering the dialog responsive to a vast number of varied paths through which users might desire to complete the dialog. To address this problem, we developed a toolkit for modeling and implementing task-based, mixed-initiative dialogs based on metaphors from lambda calculus. Our toolkit can automatically operationalize a dialog that involves multiple prompts and/or sub-dialogs, given a high-level dialog specification of it. Our current research entails incorporating the use of natural language to make the flexibility in communicating user utterances commensurate with that in dialog completion paths.

Keywords

Human-computer dialogs; mixed-initiative dialogs; mixed-initiative interaction; natural language processing.

1. PROBLEM AND MOTIVATION

The problem addressed through our research is the automatic construction of mixed-initiative, human-computer dialog systems. *Mixed-initiative interaction* is a flexible interaction strategy whereby the user and the system engage as equal participants in an activity and take turns exchanging initiative as the user progresses toward the satisfaction of a particular goal facilitated by her interaction with the system [4]. Since '[a]uthoring a dialogue is like writing a movie script with many different endings' [6], 'a central problem for mixed-initiative dialogue management is coping with utterances that fall outside of the expected sequence of the dialogue' [12]. Thus, '[d]eveloping a mixed-initiative dialog system is a complex task' [5] and '[c]reating an actual dialog system involves a very intensive programming effort' [2].

2. BACKGROUND AND RELATED WORK

Our research lies in the area of automatic mixed-initiative, dialog system construction, with a particular focus on the dialog management component (i.e., knowing what to prompt for and/or accept next based on what has already been communicated and the current utterance) of a dialog-based system [7]. Dialog-based systems can be classified based on the degree of flexibility and natural language supported (see Table 1). The increasing popularity of personal assistant technologies, such as *Siri*, *Google Now*, *Cortana*, and *Alexa*, is driving and expanding progress toward the long-standing, albeit challenging, goal of applying artificial intelligence to build human-computer dialog systems capable of understanding natural language [8]. There are multiple research projects which seek to automate the implementation of flexible, dialog-based systems [3, 5, 6] What sets our approach apart from these projects is our use of language-based concepts and operators, rather than task structures, to model dialog, which we discuss below.

		Degree of Natural Language	
		no NL ⟵ ····· ⟶ **complete NL**	
Degree of MII	**fixed**	voice	*Stanford*
	↑	commands	*CoreNLP*
	⋮	*Siri*	
	↓		
	mixed	our work ····· ⇝ our goal	

Table 1: A design space for dialog-based systems.

3. APPROACH AND UNIQUENESS

Our approach is unique in that involves thinking of dialog as a function and using concepts from programming language theory, including function currying and partially evaluation, to automatically modify that function to achieve a mixed-initiative mode of interaction. 'As the user progresses through a dialog, we think of the steps that she takes as the evaluation of a function. Changing the evaluation method of the function (or transforming the function) then corresponds to different interaction policies [11] for the dialog (i.e., ways of mixing initiative). The overall idea is that different function evaluation strategies correspond to different interaction policies for the dialog (i.e., system initiated vs. mixed-initiative) or ways of mixing initiative' [1]. The structure of an expression in our dialog-authoring notation, and the language concepts used therein, provide a pattern for implementing the dialog. Based on this foundation, we built a dialog modeling and implementation toolkit, which is capable of automatically realizing a variety of mixed-initiative dialogs given only a single, high-level specification of each.

4. RESULTS AND CONTRIBUTIONS

While '[c]reating an actual dialog system involves a very intensive programming effort' [2], our dialog authoring tool (see Fig. 1) is a contribution that simplifies that effort so that dialog designers can evaluate a variety of mixed-initiative, human-computer dialogs [1, 10]. Specifically, given q, the number of questions posed in a dialog, our system is capa-

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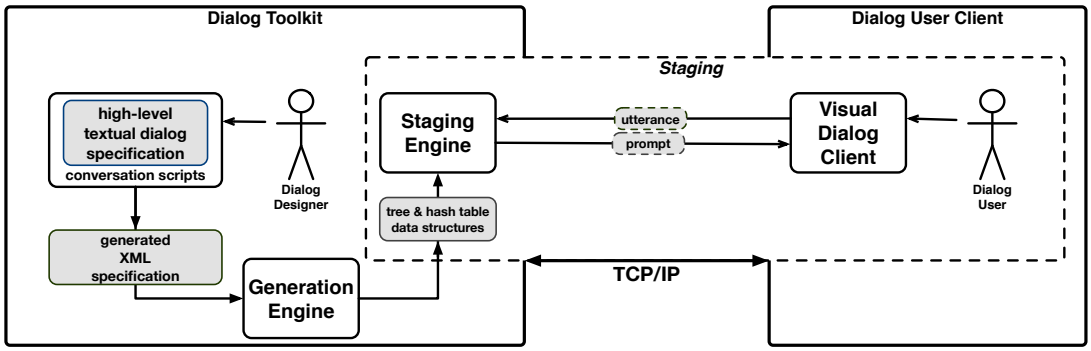

Figure 1: Conceptual design and execution of our dialog system construction tool.

ble of automatically implementing $2^{\sum_{p=1}^{q} p! \times S(q,\ p)} - 1$ dialog specifications (= 8,191 for $q = 3$)—i.e., the number of all subsets (minus the empty set) of all possible paths through a dialog involving q questions (or prompts). The expression $\sum_{p=1}^{q} p! \times S(q,\ p)$ describes the total number of paths possible through a dialog with q questions, where the *Stirling number* of a set of size m is $S(m, n) = |s(m, n)|$, and $s(m)$ is the set of all partitions of a set of size m into non-empty subsets, where m is a positive integer. This corresponds to all possible permutations (i.e., orders) of all possible partitions (i.e., combinations) of the prompts of the dialog. Our dialog toolkit is available at https://bitbucket.org/jwb_research.

This problem is important since dialog has been established as an effective mechanism through which to achieve a rich form of human-computer interaction (e.g., dialog-based systems are now used in areas as critical as health care [9]). Being able to automatically create a dialog system in a new domain is important. We feel that i) a *mixed-initiative mode of interaction* driven by user utterances and ii) communicated through the use of *natural language* (see lower right hand cell of Table 1) is the key to the effectiveness and widespread adoption of personal assistant technologies. This extended abstract discusses a research project that addresses (i), with (ii) as the focus of our current research activities.

Dialog-based systems such as *Siri* support utterances communicated through natural language, but are limited to utterances such as 'What is the weather forecast tomorrow,' and only support a low degree of mixed-initiative interaction. Thus, our current work involves enhancing our model for mixed-initiative dialog by using a *bag-of-words* model for a new dialog domain and a *k-nearest-neighbor*, or alternative, classifier to predict the context of a user utterance (i.e., map an unsolicited utterance to the dialog prompt to which it is a response). The long-term goal of our research is to improve the natural language and mixed-initiative capabilities of systems like *Siri* (see last row of Table 1).

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