Interdependencies among Dialog Acts, Task Goals and Discourse Inheritance in Mixed-Initiative Dialogs

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ABSTRACT
This paper describes a study of the interdependencies among dialog acts, task goals and discourse inheritance in mixed-initiative dialogs in the restaurants domain. Our study is based on 199 dialogs, with disjoint training (169 dialogs) and test sets (30 dialogs). Training set is annotated manually in terms of task goals and dialog acts and tagged automatically in terms of semantic and syntactic categories for each request (from the customer) and response (from the waiter). Based on observations from the process of annotation, we have written a set of category inheritance and refresh rules, which constitute our *selective* inheritance strategy. We compared the selective strategy with two control strategies – (i) no categories are inherited; and (ii) all categories are inherited throughout the dialog session. Comparison is based on the automatic identification of task goals and dialog acts. The selective inheritance strategy outperformed the two control strategies and identified the correct task goals for 92.6% of the dialog turns and the correct dialog acts for 97.8% of the utterances in the test set. We have also developed a discourse inheritance procedure which correctly handled 95.9% of the dialog turns in the test set.

1. INTRODUCTION
Continual advancements in multilingual speech and language technologies have brought the emergence of a diversity of spoken dialog systems (SDS). These systems typically support goal-oriented human-computer conversations regarding restricted application domains, e.g. real-time stock quotations, travel planning, etc. The *dialog model* in a SDS is the most critical component for the system's usability. It determines what the user is able to request from the system, in which way and at what time during the dialog session. The *mixed-initiative* dialog model allows the dialog's initiative to shift strategically in between system and user with the aim to converge on a solution for the task at hand. Hence the mixed-initiative model has good potential in achieving high task completion rates as well as user satisfaction. While it is possible to *handcraft* a sophisticated mixed-initiative dialog flow, the task is expensive, and may become intractable for complex application domains. Consequently, significant efforts have recently been devoted towards understanding mixed-initiative structures in human-human dialogs and human-computer dialogs [1-3]. Such knowledge may be incorporated in the design of mixed-initiative dialog strategies, and to help reduce handcrafting in spoken dialog systems development [4].

In this work, we study the interdependencies among dialog acts, task goals and discourse inheritance for mixed-initiative dialogs in the restaurants domain. Typically, the user presents various requests to the system that tries to fulfill them. The interaction shares many commonalities with human-human mixed-initiative dialogs involving requests from the customer and responses from the service provider / agent. In the framework of our study, communication for every request or response is characterized by its categories, dialog act(s) and task goal(s). As the dialog progresses from one turn to the next, selected categories need to be inherited in the discourse and inheritance may be dependent on the task goal or dialog act. The inherited categories augment those in the current (context-dependent) request to help determine its task goal and dialog act. The categories, task goal(s) and dialog act(s) from the request should be useful for the automatic generation of a coherent response. Understanding the interdependencies among dialog acts, task goals and discourse inheritance should enable us to design a mixed-initiative dialog model in a more principled way. Furthermore, orthogonal considerations in our framework for the *domain-dependent* task goals and *domain-independent* dialog acts facilitate separation between the *generic* and *task-specific* components in the dialog model.

2. THE CU RESTAURANTS DOMAIN
Our study is based on 199 dialogs in the restaurants domain (CU Restaurants), collected from websites and books for English learning [5-8]. The dialogs capture interactions between the customer and waiter in a restaurant, and consist of 1109 customer requests and 1320 waiter responses in total.

Table 1. An example dialog in the restaurants domain.

Customer_1	Can I have the menu, please?
Waiter_1	Yes, sir. Here. Have you decided on something, sir?
Customer_2	What is today's special?
Waiter_2	Abalone soup and stuffed tofu with rice.
Customer_3	I think it would be better to have seafood for a change. I'd like an abalone soup and a grilled fish.
Waiter_3	Anything else, sir?
Customer_4	No, thanks.
Waiter_4	You're welcome.

We divide the corpus into disjoint training (169 dialogs, with 893 customer requests and 1054 waiter responses) and test (30 dialogs, with 216 customer request and 266 waiter responses) sets. The average number of waiter and customer dialog turn pair is 5. Table 1 shows an example dialog from the corpus. The subscripts denote the counter for the dialog turns.

3. TASK GOALS, DIALOG ACTS, CATEGORIES AND ANNOTATION

3.1. Task Goals and Dialog Acts

The task goal (TG) shows the domain specific of the user's request. There are 6 task goals in the CU Restaurants domain – ASK_INFO, BILL, COMPLAINT, ORDER, RESERVATION and SERVING.

The dialog act (DA) expresses the primary communicative intention of the customer's request. We have studied a number of annotation schemes proposed for tagging dialog acts, including VERBMOBIL [11,12], VERBMOBIL-2 [9], the summer Johns Hopkins LVSCR Workshop-97 summer project (WS97 project) [12-15], DATE [2-3,16], and MITRE [1,17]. We decided to reference the VERBMOBIL-2 scheme due to the availability of detailed guidelines for tagging and their applicability to our domain. We have adopted 14 dialog acts from VERBMOBIL-2, including BACKCHANNEL, BYE, DEFER, NEGATIVE_FEEDBACK, POSITIVE_FEEDBACK, GREET, INFORM, PREFER, REQUEST_ACTION, REQUEST_INFO, REQUEST_COMMENT, REQUEST_SUGGEST, SUGGEST and THANK.

3.2. Semantic and Syntactic Categories

We have hand-defined 118 semantic and 3 syntactic categories for punctuations[1], to be extracted from the input customer requests. Examples are shown in Table 2. Within this set of categories, 88 are used for inferring the task goal of the customer's request, and 33 are used for inferring the dialog act.

Table 2. Examples of Semantic and Syntactic Categories.

	Category		Terminals
Semantic	COOKING_STYLE	→	stir fried | marinated | steamed | baked | …
Semantic	COMPLAIN	→	complain | complained | complaint|
Semantic	THANK	→	thanks | thank you | thank you very much | …
Syntactic	QUEST_MARK	→	?
Syntactic	EXCLAM_MARK	→	!
Syntactic	PERIOD	→	.

As mentioned earlier, each customer request in our training set is annotated with task goals and dialog acts. We also extracted semantic / syntactic categories from the training query automatically according to rules such as those shown in Table 2. The training queries are used to train Belief Networks for automatic identification of the task goals or dialog acts based on the input semantic and syntactic categories.

3.3. Annotating the Training Sentences

Based on the definition in VERBMOBIL-2 [9], an *utterance* is an individual unit that corresponds to a dialog act and a task goal. We segmented the dialog example from Table 1 into utterances, as shown in Table 3. For example, the waiter response *Waiter$_1$* {"Yes, sir. Here. Have you decided on something, sir?"} in Table 1 can be divided into three utterances in Table 3, including {"Yes, sir."}, {"Here."} and {"Have you decide on something, sir?"}.

Table 3. The same example dialog shown in Table 1 after utterance segmentation.

Customer$_1$	Can I have the menu, please?
Waiter$_1$	Yes, sir.
Waiter$_1$	Here.
Waiter$_1$	Have you decided on something, sir?
Customer$_2$	What is today's special?
Waiter$_2$	Abalone soup and stuffed tofu with rice.
Customer$_3$	I think it would be better to have seafood for a change.
Customer$_3$	I'd like an abalone soup and a grilled fish.
Waiter$_3$	Anything else, sir?
Customer$_4$	No,
Customer$_4$	Thanks.
Waiter$_4$	You're welcome.

Table 4. An example dialog segment from Table 1 and its task goals, dialog acts and category annotations.

Customer$_1$	What is today's special? **Categories:** {<WHAT = "what"> <TODAYSPECIAL = "today's special"> <QUEST_MARK = "?">} **Annotated Task Goal:** ORDER **Annotated Dialog Act:** REQUEST_INFO
Waiter$_1$	Abalone soup and stuffed tofu with rice. **Categories:** {<FOOD_DRINK = "abalone soup"> <FOOD_DRINK = "stuffed tofu with rice"> <PERIOD = ".">} **Annotated Task Goal:** ORDER **Annotated Dialog Act:** INFORM
Customer$_2$	I think it would be better to have seafood for a change. **Categories:** {<PREFERENCE_PHRASE = "I think"> <FOOD_DRINK = "seafood"> <CHANGE = "change"> <PERIOD = ".">} **Annotated Task Goal:** ORDER **Annotated Dialog Act:** NEGATIVE_FEEDBACK
Customer$_2$	I'd like an abalone soup and a grilled fish. **Categories:** {<PREFERNCE_PHRASE = "I'd like"> <FOOD_DRINK = "abalone soup"> <FOOD_DRINK = "grilled fish"> <PERIOD = ".">} **Annotated Task Goal:** ORDER **Annotated Dialog Act:** PREFER

[1] One may not be able to use punctuations directly if the input request is spoken, but it may be possible to detect similar information from the prosody of the utterance.

In our annotation process, we labeled each utterance with a dialog act and a task goal respectively. In our training corpus, we found cases where a single dialog turn contains multiple utterances. While the task goals of the multiple utterances are always consistent, the dialog acts are not. Hence, each dialog turn is associated with a single task goal, but possibly multiple dialog acts to reflect the user's intention. Additionally, since the waiter always tries to serve the customer in a restaurant, we further assume that in a given dialog turn *t*, the task goal of the waiter's response is always identical to that of the customer request, i.e. $TG_{Waiter,\ t} = TG_{Customer,\ t}$. An example of an annotated customer-waiter interaction from our training set is shown in Table 4.

4. SELECTIVE INHERITANCE STRATEGY

While annotating our training set, we made the following observations:

(i) Given a *context-independent* (self-contained) customer request, the *task goal* can be identified from its semantic and syntactic categories. A *context-dependent* request does not have its full set of categories for determining the task goal. We observed that the task goal of the context-dependent query in our training set is always identical to that in the previous dialog turn.

(ii) The *dialog act* of a customer request can always be identified straight from its categories. We have not seen any context-dependent requests in terms of dialog acts. See Table 5 for an illustration.

(iii) Discourse inheritance in the CU Restaurants corpus involves inheriting appropriate categories from the previous dialog turn(s) to the current dialog turn. In particular, the dialogs in our corpus seem to indicate that it is sufficient to consider only the *previous* dialog turn and its inherited discourse. Furthermore, categories that need to be inherited largely dependent on the task goal. By considering the task goal of the current customer request, we can determine the appropriate categories to inherit.

Table 5. An example dialog showing that category inheritance is not required for dialog act identification.

Customer$_1$:	*"I'd like a seafood platter, please."* **Categories:** {<PREFERENCE_PHRASE = "I'd like">, <PLEASE = "please">, <PERIOD = ".">} **Dialog Act (DA):** INFORM (This query is self-contained and states the user's preference.)
Waiter$_1$:	*"Anything else, sir?"* **Categories:** {<QUEST_MARK = *"?"*>} **DA:** REQUEST_INFO
Customer$_2$:	*"What would you recommend?"* **Categories:** {<WH_WORD = "What">, <SUGGEST = "recommend">, <QUEST_MARK = "?">} **DA:** REQUEST_SUGGEST (This query is self-contained and asks for suggestions.)

Based on these observations, we wrote five *selective* inheritance rules. Each rule corresponds to one of the task goals in the CU Restaurants domain, except for the goal of ASK_INFO, which requires no inheritance (see Table 6 for an example).

Table 6. An example dialog showing the queries with task goal ASK_INFO requires no category inheritance.

Customer$_1$:	*"What kind of food do you serve?"* **Categories:** {<WHAT = "what">, <FOOD = "food">, <SERVE = "serve">} **Task Goal (TG):** ASK_INFO
Waiter$_1$:	*"We serve a great variety of popular Japanese dishes in set courses and a la carte."* **Categories:** {<SERVE = "serve"> <RELATIVEAMOUNT = "variety">, <COUNTRY = "Japanese">, <DISH = "dishes">, <SETCOURSE = "set courses">, <FOODSTYLE = "a la carte">} **TG:** ASK_INFO
Customer$_2$:	*"When is the restaurant open for breakfast?"* **Categories:** {<WHEN = "when">, <RESTAURANT = "restaurant">, <OPEN = "open">, <MEALDESCRIPTION = "breakfast">} **TG:** ASK_INFO

The categories to be inherited selectively for each task goal are shown in Table 7. As an example, if the task goal of the customer request is BILL (i.e., an inquiry about billing), the categories <BILL>, <HOWMUCH> and <PRICEVALUE> should be inherited. This is illustrated in Table 8 with a dialog example, where categories takes on values from the latest dialog turn.

Table 7. Selective inheritance categories for each task goal.

Task Goal	Categories selected for inheritance
BILL	<BILL>, <HOWMUCH>,and <PRICEVALUE>
COMPLAINT	<COMPLAIN>, <COURSE>, <CRITICISM> and <MEALDESCRIPTION>
ORDER	<COURSE>, <MEALDESCRIPTION> and <FOOD_DRINK>
RESERVATION	<ARRANGE>, <LOCATION>, <MEALDESCRIPTION>, <NAME>, <NUMBER>, <NUMBERVALUE>, <PERSON>, <RELATIVEDATE>, <RELATIVETIME>, <RESERVE>, <SIZE>, <SMOKEOPTION>, <TABLE> and <TIME>
SERVING	<UTENSILS> and <FOOD_DRINK>

However, *over-inheritance* is found in some training dialog turns even when selective inheritance rules are applied. Over-inheritance occurs in the dialogs with confirmation (POSITIVE_FEEDBACK) or rejection (NEGATIVE_FEEDBACK). These occurrences show that although category inheritance is largely dependent on the task goal of the customer query, inheritance may also be influenced by the dialog act, i.e. both the task goal and dialog act together influence category inheritance. Table 9 shows an example dialog where over-inheritance of the category <FOOD_DRINK> occurred after the customer rejected (NEGATIVE_FEEDBACK) the waiter's suggestion.

Table 8. Categories <BILL>, <HOWMUCH> and <PRICEVALUE> are selectively inherited for queries with task goal BILL.

Customer$_1$:	*"Let me have the bill, please. How much is it?"* **Categories:** {<BILL = "bill">, <HOWMUCH = "how much">} **Task Goal:** BILL
Waiter$_1$:	*"Thank you, sir. One hundred fifty dollars, please."* **Categories:** {<PRICEVALUE = "one hundred fifty dollars">} **Task Goal:** BILL
Customer$_2$:	*"Here it is."* **Categories:** {<HERE = "here">, *<BILL = "bill">, <HOWMUCH = "how much">, <PRICEVALUE = "one hundred fifty dollars">*} **Task Goal:** BILL

Table 9. An example dialog showing over-inheritance.

Waiter$_1$:	*"Today we have fresh mushrooms too."* **Categories:** {<RELATIVEDATE = "today"> <FOOD_DRINK = "mushrooms>"} **Task Goal:** ORDER (from annotation) **Dialog Act:** SUGGEST (from annotation)
Customer$_2$:	*"I prefer something else."* **Categories:** {<PREFERENCE = "prefer">, <ELSE = "something else">, *<FOOD_DRINK = "mushrooms">* ***(Over-inheritance)***} **Task Goal Inferred:** ORDER **Dialog Act Inferred:** NEGATIVE_FEEDBACK

We have developed four refresh rules to undo over-inheritance. These rules incorporate the independencies among task goals, dialog acts, semantic and syntactic categories. Table 10 summarizes the four refresh rules. For example, the refresh rule of the task goal ORDER specifies that if the customer rejects the suggestion from the waiter, the category <FOOD_DRINK> should be disinherited, like the example dialog shown in Table 9.

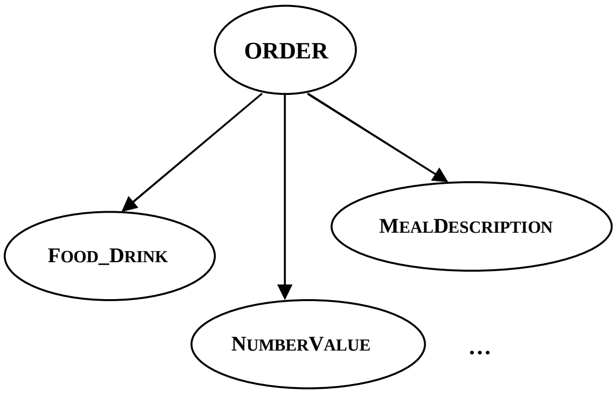
Table 10. Four refresh rules that specify categories to disinherit given the task goals and dialog acts.

$TG_{Customer,t}$	$DA_{Customer,t}$	$DA_{Waiter,t-1}$	Disinherited Categories
ORDER	NEGATIVE_FEEDBACK	SUGGEST	<FOOD_DRINK>
RESERVATION	NEGATIVE_FEEDBACK	SUGGEST	<LOCATION>
RESERATION	NEGATIVE_FEEDBACK	SUGGEST	<SMOKEOPTION>
$TG_{Customer,t}$	$DA_{Customer,t-1}$	$DA_{Waiter,t}$	Disinherited Categories
BILL	REQUEST_INFO	NEGATIVE_FEEDBACK	<PRICE_VALUE>

5. TASK GOAL AND DIALOG ACT IDENTIFICATION

We used Belief Networks (BNs) to infer the task goal and dialog act(s) for a customer request based on its inherent and inherited categories. The detailed experimental setup is adapted from that used in our previous work for the ATIS domain [17]. We have trained six BNs for each task goal. Each BN is used to infer the presence / absence of its corresponding task goal, based on the input categories. The binary decisions across all BNs are combined to identify the task goal of the customer request. If all BNs vote negative for their respective goals, the request may be context-dependent or out-of-domain (OOD). Similarly, we have trained thirteen BNs to identify the dialog act for each customer request except for INFORM. If all thirteen BNs vote negative, the dialog act is set to INFORM – a catch-all category as used in VERBMOBIL-2. We have used the simplified topology of BNs which is identical to a naïve Bayes setup. Figure 1 illustrated a simplified BN for the task goal ORDER.

Figure 1. A simplified BN for the task goal ORDER.



Evaluation indicates 97.8% of the test set *utterances* have correctly identified dialog acts. Since task goal identification can be affected by category inheritance, we experimented with three inheritance strategies. We trained a set of BNs for each inheritance strategy. We also applied the corresponding inheritance strategy to the test set. Figure 2 shows the average task goal identification performance for the three inheritance strategies based on the test set. Selective inheritance gave the best performance.

Figure 2. Test set accuracies for task goal identification based on different category inheritance strategies. Performance in task goal identification is measured in terms of the *dialog turns*, because each turn has a single task goal only.

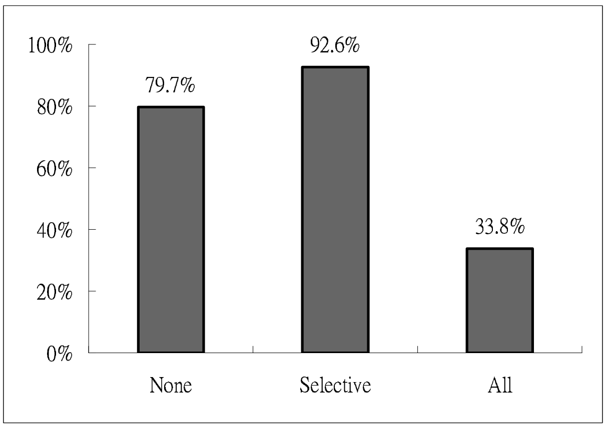


Table 11 provides an example of how the selective inheritance strategy gave rise to the correct task goal, but other strategies identified an incorrect task goal. The categories in italics are inherited from discourse.

Table 11. The use of different inheritance strategies for task goal identification.

Waiter$_1$:	*"Your seafood platter costs one hundred dollars. I'm afraid this voucher cannot cover the cost of your meal. Would you mind paying the extra in cash?"*
	Categories: {<FOOD_DRINK = "seafood platter"> <COST = "costs"> <PRICEVALUE = "one hundred dollars"> <PAYMETHOD ="voucher"> <COST = "cost"> <MEALDESCRIPTION = "meal"> <PAY ="paying"> <EXTRA = "extra"> <PAYMETHOD = "cash"> "} **Task Goal:** BILL
Customer$_2$:	*"OK. But how much is the voucher worth?"*
	<u>No inheritance</u> **Categories:** {<HOWMUCH = "how much">, <PAYMETHOD = "voucher">} **Task Goal inferred:** OOD (out-of-domain)
	<u>Selective inheritance</u> **Categories:** {<HOWMUCH = "how much"> <PAYMETHOD = "voucher"> *<PRICEVALUE = "one hundred dollars">*}**Task Goal inferred: BILL**
	<u>All inheritance</u> **Categories:** {<HOWMUCH = "how much"> <PAYMETHOD = "voucher"> *<FOOD_DRINK = "seafood platter> <COST = "costs"> <PRICEVALUE = "one hundred dollars"> <PAYMETHOD="voucher"> <COST = "cost"> <MEALDESCRIPTION= "meal"> <PAY="paying"> <EXTRA = "extra"> <PAYMETHOD = "cash">*}**Task Goal inferred:** OOD

6. PROCEDURE FOR DISCOURSE INHERITANCE

We have developed the following discourse inheritance procedure for handling customer requests in our mixed-initiative dialog corpus. Discourse inheritance includes both category inheritance and task goal inheritance. Table 12 describes the discourse inheritance procedure.

Table 12. Discourse inheritance procedure determined based on the CU Restaurants Corpus.

Step 1	Parse for **categories** in the incoming customer request ($C_{Customer,\ t}$)
Step 2	Infer the **task goal** ($TG_{Customer,\ t}$) of the request using the trained BNs and $C_{Customer,\ t}$ If $TG_{Customer,\ t}$ = nil (all BNs vote negative), then $TG_{Customer,\ t} = TG_{Waiter,\ t-1}$ (treat request as context-dependent, perform **task goal inheritance** based on previous dialog turn.)
Step 3	Infer the **dialog act** ($DA_{Customer,\ t}$) of the request using the trained BNs and $C_{Customer,\ t}$ If $DA_{Customer,\ t}$ = nil (all BNs vote negative), $DA_{Customer,\ t}$ = INFORM
Step 4	Apply selective **category inheritance rules** based on $TG_{Customer,\ t}$ and $DA_{Customer,\ t}$. and **category refresh rules** based on $TG_{Customer,\ t}$, $DA_{Customer,\ t}$., $DA_{Customer,\ t-1}$, $DA_{Waiter,\ t}$ or $DA_{Waiter,\ t-1}$

Step 2 specifies *task goal inheritance*, which we found to be necessary for context-dependent customer requests. The BNs often label these requests as OOD, i.e. all BNs vote negative for their corresponding task goals. Under such circumstances, we inherit the task goal of the previous dialog turn, i.e. $TG_{Customer,t}=TG_{Waiter,t-1}$. With task goal inheritance, we improved task goal identification of the test set from 92.6% (see Section 5) to 93.2%.

The *discourse inheritance procedure* incorporates our findings in the interdependencies among task goals, dialog acts and category inheritance. Evaluation shows that this procedure correctly handled 95.9% of *dialog turns* in our test set.

7. CONCLUSIONS AND FUTURE WORK

This paper describes a study of the interdependencies among dialog acts, task goals and discourse inheritance in mixed-initiative dialogs in the CU Restaurants domain. Our study is based on 199 dialogs in the restaurants domain, with disjoint training (169 dialogs) and test sets (30 dialogs). Our training set is first annotated manually in terms of task goals and dialog acts and tagged automatically in terms of semantic and syntactic categories for each customer request and waiter response. Based on the annotation process, we observed the following:

1. The task goal of a context-independent customer request can be identified from its categories, while the task goal of a context-dependent request can be inherited from the previous dialog turn.
2. Dialog act identification does not require category inheritance, while task goal identification does.
3. Category inheritance is largely dependent on the task goals of the current query. However in some cases it is also influenced by the dialog act in the cases of confirmation or rejection.

We have written a set of category inheritance and refresh rules, which constitute our *selective inheritance strategy*. We used Belief Networks (BNs) to automate identification of task goals and dialog acts based on input categories. Selective category inheritance outperformed two alternate control strategies where none or all of the categoreis are inherited. The selective strategy achieved correct task goal identification for 92.6% of the dialog turns and correct dialog act identification for 97.8% of the utterances in the test set. We have also developed a *discourse inheritance procedure*, which can correctly handle 95.9% of the dialog turns in the test set. In the near future, we will work on cooperative response generation in the CU Restaurants domain.

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