Using State Transition Networks to Analyze Multi-Party Conversations in a Serious Game

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Abstract. As players interact in a serious game, mentoring is often needed to facilitate progress and learning. Although human mentors are the current standard, they present logistical difficulties. Automating the mentor's role is a difficult task, however, especially for multi-party collaborative learning environments. In order to better understand the conversational demands of a mentor, this paper investigates the dynamics and linguistic features of multi-party chat in the context of an online epistemic game, Urban Science. We categorized thousands of player and mentor contributions into eight different speech acts and analyzed the sequence of dialogue moves using State Transition Networks. The results indicate that dialogue transitions are relatively stable with respect to gameplay goals; however, task-oriented stages emphasize mentor-player scaffolding, whereas discussion-oriented stages feature player-player collaboration.

Keywords: collaborative learning, epistemic games, natural language processing

1 Introduction

Serious games are increasingly becoming a popular, effective supplement to standard classroom instruction [1]. Some classes of serious games provide microworlds [2] that allow players to explore a virtual environment. These simulations have ideal and often simple problems with targeted scaffolding to help users identify important concepts and think critically about them. Multi-party chat is pervasive in serious games and crucial to success in multi-player recreational games, including the epistemic games [3, 4, 5] that will be addressed in the present study.

Epistemic games and collaboration can be effective environments for learning [6], but a critical element for success in these environments is access to some form of directed help. A substantial body of research suggests that mentoring is needed in order to facilitate learning tools, such as reflection, elaboration, scaffolding, modeling, and so forth [7, 8, 9]. Without this, student learning is minimal.

While mentoring is a necessary element for learning in epistemic games, this role is almost exclusively provided by a human at the present time. However, the cost

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incurred with training a human mentor, as well as logistics (e.g., availability), represent a critical barrier for widespread use of a collaborative epistemic game. Consequently, if the role of the mentor could be automated, it would allow an established epistemic game to be scaled up for widespread use. Although great strides have been made in automating one-on-one tutorial dialogues [10], multi-party chat presents a significant challenge for natural language processing. The goal of this paper, then, is to provide a preliminary understanding of player-mentor conversations in the context of an epistemic game, specifically *Urban Science*.

Urban Science is an epistemic game created by education researchers at the University of Wisconsin-Madison, designed to simulate an urban planning practicum experience [7]. During the game, players communicate with other members of their planning team, as well as with an adult mentor role-playing as a professional planning consultant. Urban Science consists of 19 distinct stages, each of which has one of two functions, *task-oriented* or *discussion-oriented* (with 13 and 6 stages, respectively). The task-oriented stages have more concrete actions to perform. Discussion-oriented stages have high interactivity, discussion, and reflection.

It is plausible that the different educational goals of each stage type may have corresponding differences in the conversational patterns between players and mentors. To investigate these patterns, the conversations between the mentor and players were analyzed with respect to meaning, syntax, and discourse function by speech act classification. These categorized speech acts were analyzed to identify speech act sequences in the conversations, represented as State Transition Networks (STN).

1.1 Speech Act Classification and State Transition Networks

Analyses of a variety of corpora, including chat and multiparty games, have converged on a set of speech act categories that are both theoretically justified and that also can be reliably coded by trained judges [11, 12]. Our classification scheme has 8 broad categories: Statements, Requests, Questions, Reactions, Expressive Evaluations, MetaStatements, Greetings, and Other. After classifying individual speech acts, pairs of speech acts can be joined in STNs. STNs specify the speech act transitions both within and between conversation participants with respect to specific speakers and the associated speech act categories.

Discourse acts in educational contexts have been documented in great detail in the context of classroom discourse [13, 14] and human tutoring [15, 16]. For example, a common three-step sequence in classrooms is: "Teacher Question → Student Answer → Teacher Feedback Response" [17]. The goal of this paper is to identify the conversational patterns in multi-party conversations in an epistemic game (such as Urban Science) with the ultimate objective of automating the mentor's role.

1.2 Hypotheses

First, we predict that our analyses will identify speech acts and transitions common to both task- and discussion-oriented stages. For example, aforementioned research indicates that mentoring is critical to maximize learning [7, 8, 9]. Thus, mentor contributions should constitute the most pivotal nodes in the STNs of both types of stages. The research also suggested that mentor questions often initiate conversational sequences, which are followed by player responses and then feedback on the response. This dynamic is well-established and should be evident across both formats.

In addition to commonalities, we also seek to pinpoint some differences between stage types. In the task-oriented stages, goal achievement is a priority, suggesting that mentor requests would be more relevant. Similarly, task-based stages should also feature questions by the players about how to proceed. Most importantly, we expect two distinct epistemic networks to emerge: scaffolding and collaboration. Scaffolding occurs when mentor responses to player contributions help guide players to the next step. This should be essential to facilitating goal completion in task-oriented stages. Conversely, collaboration represents meaningful interactions between players. This should be more evident in the discussion format, as players interact and reflect upon their previous actions.

2 Methods

Twenty-one high school-aged participants and two mentors played Urban Science for ten hours over three days Players communicated with each other and the mentor via a chat window. Player and Mentor chat contributions were automatically categorized into speech acts using the Naive Bayes classification algorithm on word features. The classification compares favorably to trained human coders with a kappa of 0.677, compared to a kappa of 0.797 between two humans [18].

STNs were created by calculating the conditional probability of each transition between speech acts as well as the overall frequency of each speech act in the corpus. For example, a mentor statement might be followed by a player reaction 28% of the time, and a player reaction might constitute 0.8% of the entire corpus. For each transition, a minimum conditional probability threshold of 15% was used for inclusion in the network, as well as an overall frequency of 0.3%. Additionally, although there are only two roles in the game (player and mentor), one crucial piece of information that the STNs can provide is the identity of the speaker. Specifically, in the case of adjacent player contributions, it is critical to distinguish whether the response is a follow-up from the same player ("P → P") or whether it is a reply by some Other Player ("P → OP"). This distinction helps in identifying player collaborations.

3 Results

Our analysis of the Urban Science data initially classified contributions into individual speech acts, then calculated the conditional probabilities for each transition, and then the overall frequencies/likelihoods for each speech act category. We expected to find some commonalities and differences between two different types of interactions during gameplay, namely task-oriented and discussion-oriented stage types. We found that the correlation between transition conditional probabilities was quite large, r (318) = 0.63, p < .001, which supports the notion that conversation dynamics are largely stable. Inspection of the STNs for both formats unveils these common patterns, but also highlights some transitions that distinguish the two. The STNs for task- and discussion-oriented stages are shown in Figures 2 and 3, respectively.

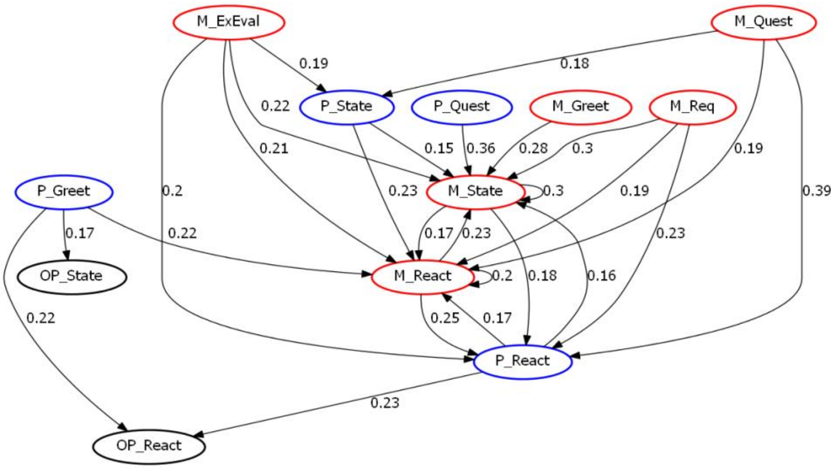

Fig. 1. State Transition Network for Task-oriented stages.

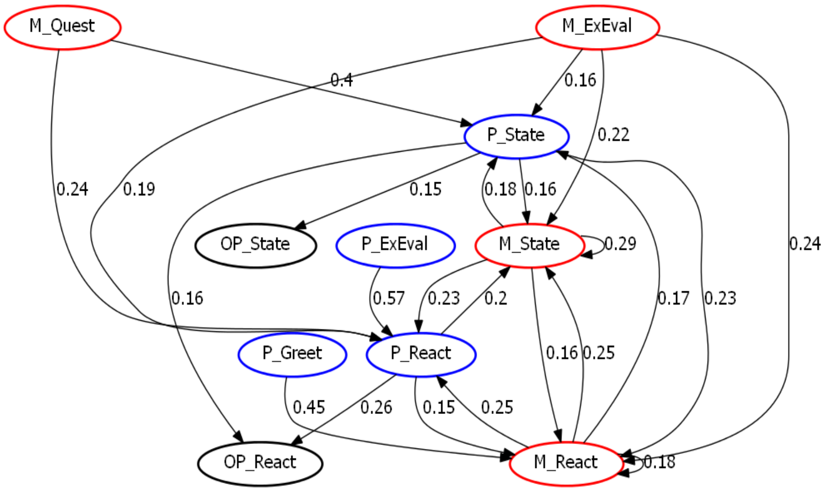

Fig. 2. State Transition Network for Discussion-oriented stages.

Our first prediction was that mentor contributions would constitute the most pivotal nodes in the STNs of both stage types, reflecting the importance of the mentor in student learning. This was supported by the relative importance of mentor statements and mentor reactions in both STNs. We also predicted that mentor questions would initiate conversational sequences. Figures 2 and 3 both suggest that mentor questions (along with expressive evaluations) were crucial in triggering dialogue progressions.

Additionally, mentor questions in both networks were typically followed by player statements or reactions, which were in turn followed by reactions or statements from the mentor or another player. This suggests the “Question → Response → Feedback” sequence that was discussed previously [17].

With respect to differences in stage type, mentor requests and player questions played a larger role in the task-oriented stages, in line with our predictions, whereas in the discussion-oriented stages, player statements and expressive evaluations had a higher impact. We also expected distinct epistemic patterns to emerge between the two stage types, namely scaffolding and collaboration. The distinguishing feature of these patterns is the relative frequency of a mentor response to a player contribution versus a response by some other player. Whereas the task-oriented STN features more mentor nodes (indicating scaffolding), the discussion-oriented STN produced similar OP nodes. However, the OP contributions in the discussion-oriented stages were more likely to be a response to player statements and reactions (i.e., the final link in the “Question → Response → Feedback” chain), as opposed to responses to greetings, which are unlikely to be meaningful. These observations support the prediction that scaffolding is more important to facilitate the goal achievement for task-based gameplay, whereas the discussion-based format emphasizes student collaboration.

4 Conclusion and Future Work

We expected that particular transitions between speech acts would be common within both types of gameplay in Urban Science, task- and discussion-oriented. The correlation of transition between the two stage types was surprisingly strong, indicating that transitions are relatively stable across different modes of gameplay. Despite the overlap in transition frequencies between task- and discussion-oriented stages, we were able to identify some crucial differences between the two types. Mentor requests and player questions reflected the goal-driven activities of the task-oriented stages, whereas the discussion-oriented stages showed greater emphasis on player statements and expressive evaluations as they reflected on previous game actions. The two stages also differed in the final link of the “Question → Response → Feedback” sequence, where the feedback was more likely to be provided by the mentor in the task-oriented stage (indicating scaffolding), but in the discussion format, other players were increasingly likely to respond (suggesting collaboration).

The results of the presented analyses are applicable to a number of current and future investigations. First, we are currently analyzing additional chat room interactions in order to replicate these findings and assist in automating the role of the mentor. This includes predicting points in the conversation where a mentor should provide a contribution, as well as the appropriate speech act at a given point.

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