Critical Question ordering on argumentation-based dialogues

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Abstract.
In multi-agent scenarios where the communication overload is important the number of questions exchanged may impact negatively on the efficiency of the MAS. We present in this report different critical question orderings in simulated dialogues about plans to identify the best ordering in terms of the number of questions exchanged. In the type of dialogue we are considering the question-answer exchange represents the phase where agents exchange more information.

Keywords. Agent Co-operation, Argumentation Schemes, Critical Questions

1. Introduction

This paper presents an analysis on different question orderings aimed to minimize the number of questions exchanged in dialogues about plans. In this report we present extra dialogue simulations that complement the ones presented in [7] and [6] where we implemented an extra strategy (a dummy strategy) to prioritize questions. Our aim with these experiments is to have more elements to analyze the use of an ordering strategy in automated agent dialogues. In [7] and [6], we presented a random strategy that in fact used a random ordering but the process to identify questions was not performed (we consider the “question identification” part of the strategy). Thus, the comparison between using a strategy or not was not relevant since the number of exchanged questions when using the random strategy was much higher because the agents posed all the available questions for all the elements presented in the plan proposal.

The “dummy strategy” presented in this report makes use of the method to identify questions together with a random (or dummy) ordering of the question types with the purpose of provide a direct comparison between strategies.

2. Argumentative Approach to Plan Selection

Co-operative distributed planning focuses on how planning can be extended into a distributed environment, where the process of creating and executing a plan can involve actions and interactions of a number of participants [2]. Some research in distributed planning focuses on mechanisms for plan coordination [3]; we propose here the use of

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argumentation-based dialogues to critique plans. The dialogue focuses then on the evaluation of plans taking into account that agents have different beliefs about the world and different preferences. Preferences over plans are used to try to identify the best possible plan for both agents. We believe our approach presents an advantage because the preferences are applied in the dialogue together with the mechanism to evaluate and select the plans rather than as a separate process.

Our plan proposal (*ASP*) can be expressed as an argumentation scheme as follows (full details of the argumentation scheme are given in [8]): *ASP: Given a social context and initial state (current circumstances) in which a set of preconditions hold, a plan should be performed to achieve new circumstances, causing a set of postconditions to hold, which will realize the plan-goal, which will promote a set of values* [2]. A benefit of having critical questions associated with an argument scheme is that the questions enable dialogue participants to identify points of challenge to an argument or locate premises in the argument that can be recognized as questionable. We classify our set of sixty five critical questions (listed in [4]) for the plan proposal scheme *ASP* into 7 layers: (1) an action and its elements, (2) the timing of a particular action, (3) the way actions are combined, (4) the plan proposal overall, (5) the timing of the plan proposal, (6) side effects, (7) alternative options.

3. Strategy to Select Critical Questions

In open environments it is in principle desirable that agents engaged in a dialogue have the freedom to pose any question, but in some scenarios agents may be restricted by preconditions imposed by the domain or the dialogue protocol. While this restricts the freedom of the agents, it typically has benefits in terms of the efficiency and coherence of the dialogue. We focus on the process of selecting from a set of critical questions assuming the communicative act, in this case $question()$, has been selected but the content remains to be determined. A different problem is to select the communicative act itself and different strategies could be applied as in [1] where the authors define a strategy for dialogue move selection. In this paper we consider a strategy to be a process with two steps: (1) identify the differences between the respondent agent's (RES) representation of the world and the proposal asserted by the proponent agent (PRO) to instantiate potentially useful questions and (2) prioritize and select questions to pose. We now discuss these two steps in more detail.

3.1. Belief Representation Alignment

In this step RES identifies questions to pose based on the information presented by PRO in the proposal. The process used to identify questions compares the information of the proposal (the goal, the initial state, the actions, the norm and the values) against the RES local representation of the world. If there is an inconsistency detected, the related question is added to a list of potentially useful questions. In a co-operative dialogue we believe that agents first need to agree on the representation of the world to generate consistent plans. In a continuously changing environment this may be very difficult. When agents agree at some point on a set of circumstances, a change could happen that inval-

[2]Following [8], values are social interests of agents that can be promoted by moving between states.

idates several coordination agreements between agents. This means the protocol semantics should allow questions -attacks about the domain- to be posed more than once. This process takes into account the fact that some questions depend on the outcome of others. For example, when checking for the validity of an action element, if the action is not valid there is no point considering the question of whether the action is possible.

3.2. Question Prioritizing and Selection

We now present a more detailed analysis of the critical questions to classify them, taking into account a finer grained description. When categorizing the questions our aim is to identify their intrinsic purpose in the dialogue, which we use to give them a priority in our strategies. From a general perspective, in a planning scenario, critical questions may refer to the domain, to the plan, or to the scheduling of the actions. We take this categorization as our first ordering criterion. We want first to resolve inconsistencies about the domain (to create valid plans), then focus on the plan itself and finally focus on the scheduling elements of the plan. A typical AI planning process in fact follows the same order: a valid domain and problem representation are the input of a generic planner algorithm and once the plan is created a scheduling process can be applied to it. Our second categorization criterion refers to the ways a proposal could be questioned using different types of critical question. From our set of questions, a question can challenge: the suitability of an element (*e.g. Are there any side effects when executing action α?)* [3], the validity of an element (*e.g. Are the termination conditions of action α valid?*), the possibility of an element (*e.g. Are the current circumstances possible?*), the possibility in time of an element (*e.g. Is it possible to execute action α at time t*) or evaluate other possible better alternatives (*e.g. Is there an alternative plan to reach the goal?*).

This categorization provides an order in which questions can be posed. We first want to establish that the plan proposed is "suitable" for the context and the goal and the plan's acceptability based on the motives that it satisfies. We include in the suitability questions, for example, *Do the new circumstances already pertain?* It may not make sense to argue about the validity of an element if the intrinsic motives to perform the plan are not fully agreed by all parties. Once agreed on the suitability, we can question the validity of the elements to resolve conflicts about the representation of the world between agents. Once agents agree on the validity of the elements, the possibility of the plan can be addressed. Possibility questions lead us to address specific actions where we follow the same order: suitability, validity and possibility for specific actions. Finally, we focus on alternatives: the plan proposed may be acceptable for both agents but still a better plan may be available. We combine both categorizations to obtain ordering strategy $s1$ presented in Table 1. A second strategy $s2$ is also created where we change the order, considering first validity questions is also presented in Table 1.

A random ordering of question types named $s3$ (e.g. 1. plan suitability, 2. termination condition validity 3. alternative options etc.) was created to provide a comparison point with our two ordering strategies.

[3] A side effect is an outcome of the action that was unintended, and could promote or demote a value, though our implementation is restricted to consider only negative side effects.

Table 1. Priority order in which questions are considered for both strategies

	$s1$ question priority order		$s2$ question priority order
1.	Plan suitability	1.	Actions' validity.
2.	Actions' suitability	2.	Plan elements' validity.
3.	Norms suitability	3.	Plan suitability
4.	Plan elements' validity	4.	Actions' suitability
5.	Actions' validity.	5.	Norms suitability
6.	State of the world validity	6.	Plan elements' possibility
7.	Actions' possibility.	7.	Actions' possibility.
8.	Plan elements' possibility.	8.	State of the world validity
9.	Alternative actions.	9.	Alternative actions.
10.	Alternative plans.	10.	Alternative plans.

4. Implementation

We describe in this section experiments that show the effect of following our strategies. We present a scenario where two agents (John and Paul) have to agree on a plan to travel together through different cities to a conference in Paris. Agents have different plans and a different preference over them. Values are linked to the plans according to the the actions that comprise them. The values used are: value $v_1 = money$, the cheapest option, value $v_2 = time$, the fastest option, value $v_3 = friendship$, travelling with a friend, and value $v_4 = comfort$, the most comfortable way to travel.

A dialogue simulation in our experiments consists of the following steps: (1) PRO starts the dialogue through a tuple centre [4]; (2) PRO selects his preferred plan according to its value preference; (3) PRO's dialogue manager (DM) transforms the plan into a proposal object; (4) PRO creates a valid tuple and posts it to the tuple-centre (the protocol embedded in the tuple-centre validates the locution and RES gets its turn to speak); (5) RES acknowledges the proposal and starts questioning PRO over the plan presented using a strategy (plans are questioned individually until one plan is accepted); (6) if RES has a plan to propose as an alternate the agents change roles and the process starts again from (2); (7) Once the questioning process finishes if the preferred plan for both is the same the dialogue finishes, otherwise the plan with more promoted values is selected.

Values promoted by agents' plans (promoted (+), demoted (-) or neutral (=)) are presented in table 2. Although each individual action could be associated with a value, for the sake of simplicity here we will only consider values related to the plan as a whole.

Table 2. Agents' plans promoted values

Plan	**Promoted values**
p_1 - Coach	$v_1 = money$
p_2- Trains	$v_3 = friendship$, $v_4 = comfort$
p_3 - Flight	$v_2 = duration$
p_4 - Coach-Train	$v_3 = friendship$

Test cases are formed of the agents loaded with information about the world (norms that represent the "social context", an initial state, a set of action specifications) a set of

[4]The dialogue protocol was implemented in the *TuCSoN* (Tuples Centres Spread over the Network) blackboard platform [9]. For a full description see [5].

plans, a set of values and a preference order over values. In the different test cases we change the validity of some elements in the plans and/or world representation for each agent to create different runs. We give agents three different sets of information about the world and plans (table 3) and we combine them with three different preference orders (table 4) for the agents to generate our nine test cases. The validity of elements (actions conditions, action effects, norms) is represented using a "token attribute" associated with each element. That the "token" is $false$ represents the element validity against the context has expired. In test case A John's plans p_1, p_2, p_3 are invalid to induce questions about the validity and possibility of the action elements. The norms and initial state of Paul are not valid and generate possibility and suitability questions. In test case B John's initial state is not valid nor is his plan p_2. These runs aim to question the proposals mainly at the plan suitability level.

Table 3. Test case specifications

Test case	**John's Plans**		**John's Beliefs**		**Paul's Plans**		**Paul's Beliefs**	
B	PL_1	×	Social constraints	✓	PL_4	✓	Social constraints	×
	PL_2	×	Initial state	✓	PL_5	✓	Initial state	×
	PL_3	×	Action specification	✓			Action specification	✓
	PL_6	✓						
C	PL_1	✓	Social constraints	✓	PL_5	✓	Social constraints	✓
	PL_2	×	Initial state	✓	PL_4	×	Initial state	✓
	PL_3	×	Action specification	✓			Action specification	✓
	PL_6	✓						
D	PL_1	✓	Social constraints	✓	PL_4	✓	Social constraints	✓
	PL_2	×	Initial state	×	PL_5	✓	Initial state	✓
	PL_3	✓	Action specification	✓			Action specification	✓
	PL_6	✓						

From the complete list of sixty five critical questions in [4] we have implemented twenty eight questions for these experiments related to validity, possibility and suitability for the action and plan specifications, alternate plans and side effect questions. For these experiments we omitted action-combination and time-related questions to avoid the complexity of implementing those characteristics at this stage. To analyze the results we

Table 4. Test cases preferences

Test case	John preference: Value preference order	John preference: Preferred value in plan	Paul preference: Value preference order	Paul preference: Preferred value in plan
1	$v_1 > v_4 > v_3 > v_2$	v_1 in PL_1	$v_3 > v_4 > v_1 > v_2$	v_3 in PL_4
2	$v_3 > v_2 > v_1 > v_4$	v_3 in PL_2	$v_3 > v_4 > v_1 > v_2$	v_3 in PL_4
3	$v_2 > v_1 > v_3 > v_4$	v_2 in PL_1	$v_2 > v_4 > v_1 > v_3$	v_2 in PL_5
4	$v_3 > v_1 > v_4 > v_2$	v_3 in PL_2	$v_1 > v_2 > v_4 > v_3$	v_1 in PL_4
5	$v_1 > v_4 > v_3 > v_2$	v_1 in PL_1	$v_2 > v_4 > v_3 > v_1$	v_3 in PL_4

record for each run the number of proposals, the number of questions and the outcome of the dialogue. In tables 5 - 7 we present the results of the dialogue runs. We discuss now the results of a selection of the runs and conclude with an overall analysis of the results. The results present the number of proposals and the order in which they were evaluated, together with the outcome of the evaluation (a check mark (✓) for an accepted proposal, and a cross ($\times$) for a rejected proposal). Finally, we present the number of questions evaluated and the selected plan.

We have implemented agents that engage in a dialogue to select the best valid possible plan for both. The dialogue takes a persuasion approach and makes use of critical questions to evaluate the plan proposal at several levels.

Strategy $s2$ performs better (in terms of the number of questions exchanged) in the first four orderings (B1-B4). In run B5 strategy $s1$ is the best performer. We ran dialogue simulations with the random ordering $s3$ fifteen times (for test cases B C and D) and the results show that in general when using either strategy $s1$ or $s2$ the result in terms on number of questions exchanged. In general strategies $s3$ and $s2$ perform better than the random ordering in most of the cases. We could summarize the results of these simulations with the following points:

- Any strategy is better than a random question selection.
- The best strategy requires consideration of the problem.
- The priority order is important but problem dependant.
- A random order is as good as an inappropriate order but not as good as the appropriate one.

Table 5. Test case B when John starts the dialogue. Strategy $s3$ does not perform better in any simulation.

Test case	Run	Strategy	Proposals	No. Q.	Plan selected
B1	1.	$s1$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_4(\times)$	23	PL_6
	2.	$s2$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_4(\times)$	12	PL_6
	3.	$s3$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_4(\times)$	21	PL_6
B2	1.	$s1$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	15	PL_6
	2.	$s2$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	9	PL_6
	3.	$s3$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	14	PL_6
B3	1.	$s1$	3 - J: $PL_3(\times), PL_6(\checkmark), P: PL_5(\times)$	13	PL_6
	2.	$s2$	3 - J: $PL_3(\times), PL_6(\checkmark), P: PL_5(\times)$	8	PL_6
	3.	$s3$	3 - J: $PL_3(\times), PL_6(\checkmark), P: PL_5(\times)$	12	PL_6
B4	1.	$s1$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	15	PL_6
	2.	$s2$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	9	PL_6
	3.	$s3$	3 - J: $PL_2(\times), PL_6(\checkmark), P: PL_4(\times)$	20	PL_6
B5	1.	$s1$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_5(\times)$	15	PL_6
	2.	$s2$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_5(\times)$	23	PL_6
	3.	$s3$	5 - J: $PL_1, PL_2, PL_3(\times), PL_6(\checkmark)$ P: $PL_5(\times)$	21	PL_6

5. Conclusions

Our approach presents a way for agents to cooperate, but allows the agents to reach agreements using individual preferences in the dialogue. The random strategy $s3$ introduced in this report does not perform better in any of the simulated dialogue runs which confirms that the order provided is right. One or both of our strategies ($s1$, $s2$) perform better than the random approach in our simulations. Nevertheless, the number of questions it is no significantly different between the random approach and our strategies.

We showed that the use of a strategy to select questions in a dialogue regarding plans is beneficial, although different strategies performed better in different cases. We identified the characteristics which influence the performance of the strategies. The strategy

Table 6. Test case C when John starts the dialogue

Test case	Run	Strategy	Proposals	No. Q.	Plan selected
C1	1.	$s1$	2 - J: $PL_1(\checkmark)$, P: $PL_4(\times)$	6	PL_1
	2.	$s2$	2 - J: $PL_1(\checkmark)$, P: $PL_4(\times)$	4	PL_1
	3.	$s3$	2 - J: $PL_1(\checkmark)$, P: $PL_4(\times)$	5	PL_1
C2	1.	$s1$	3 - J: $PL_2(\times)$, $PL_6(\checkmark)$, P: $PL_4(\times)$	8	PL_6
	2.	$s2$	3 - J: $PL_2(\times)$, $PL_6(\checkmark)$, P: $PL_4(\times)$	5	PL_6
	3.	$s3$	3 - J: $PL_2(\times)$, $PL_6(\checkmark)$, P: $PL_4(\times)$	7	PL_6
C3	1.	$s1$	3 - J: $PL_3(\times)$, $PL_4(\times)$, P: $PL_5(\checkmark)$	7	PL_5
	2.	$s2$	3 - J: $PL_3(\times)$, $PL_4(\times)$, P: $PL_5(\checkmark)$	5	PL_5
	3.	$s3$	3 - J: $PL_3(\times)$, $PL_4(\times)$, P: $PL_5(\checkmark)$	6	PL_5
C4	1.	$s1$	3 - J: $PL_2(\times)$, $PL_6(\checkmark)$, $P : PL_4(\times)$	8	PL_6
	2.	$s2$	3 - J: $PL_2(\times)$, $PL_6(\checkmark)$, P: $PL_4(\times)$	5	PL_6
	3.	$s3$	J: 3 - $PL_2(\times)$, $PL_6(\checkmark)$, P: $PL_4(\times)$	9	PL_6
C5	1.	$s1$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$ P: $PL_5(\times)$	10	PL_6
	2.	$s2$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$ P: $PL_5(\times)$	12	PL_6
	3.	$s3$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$ P: $PL_5(\times)$	11	PL_6

where possibility questions are put first in the questioning order performs better for most cases because inconsistencies are found mainly in the plan representation. We then believe the strategy should be tailored to the context in which the dialogue develops and modified as the dialogue develops to reduce communication overload.

Table 7. Test case D when John starts the dialogue

Test case	Run	Strategy	Proposals	No. Q.	Plan selected
D1	1.	$s1$	5 - J: PL_1, PL_2, PL_3,$PL_6(\times)$, P: $PL_4(\checkmark)$	13	PL_4
	2.	$s2$	5 - J: PL_1, PL_2, PL_3,$PL_6(\times)$, P: $PL_4(\checkmark)$	15	PL_4
	3.	$s3$	5 - J: PL_1, PL_2, PL_3,$PL_6(\times)$, P: $PL_4(\checkmark)$	13	PL_4
D2	1.	$s1$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	13	PL_4
	2.	$s2$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	15	PL_4
	3.	$s3$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	13	PL_4
D3	1.	$s1$	5 - J: PL_3, PL_6, PL_2,$PL_1(\times)$, P: $PL_5(\checkmark)$	13	PL_5
	2.	$s2$	5 - J: PL_3, PL_6, PL_2,$PL_1(\times)$, P: $PL_5(\checkmark)$	15	PL_5
	3.	$s3$	5 - J: PL_3, PL_6, PL_2,$PL_1(\times)$, P: $PL_5(\checkmark)$	13	PL_5
D4	1.	$s1$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	13	PL_4
	2.	$s2$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	15	PL_4
	3.	$s3$	5 - J: PL_2, PL_6, PL_1,$PL_3(\times)$, P: $PL_4(\checkmark)$	13	PL_4
D5	1.	$s1$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$, P: $PL_5(\times)$	8	–
	2.	$s2$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$, P: $PL_5(\times)$	12	–
	3.	$s3$	5 - J: PL_1, PL_2, $PL_3(\times)$, $PL_6(\checkmark)$, P: $PL_5(\times)$	12	–

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