

Dialogue as Discourse: Controlling Global Properties of Scripted Dialogue*

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Abstract

This paper explains why *scripted dialogue* shares some crucial properties with discourse. In particular, when scripted dialogues are generated by a Natural Language Generation system, the generator can apply revision strategies that cannot normally be used when the dialogue results from an interaction between autonomous agents (i.e., when the dialogue is not scripted). The paper explains that the relevant revision operators are best applied at the level of a dialogue plan and discusses how the generator may decide when to apply a given revision operator.

Controlling Global Properties in Text Generation

A Natural Language Generation (NLG) system puts information into words. When doing this, the system makes a large number of *decisions* as to the specific way in which this is done: aggregating information into paragraphs and sentences, choosing one syntactic pattern instead of another, deciding to use one word rather than another, and so on. For many purposes, such decisions can be made on the basis of local information. The choice between an active and a passive sentence, for example, usually does not take other decisions (such as the analogous choice involving another sentence) into account. In slightly more difficult cases, the decisions of the generator can be based on decisions that have been taken *earlier*. For example, the generator may inspect the linguistic context to the left of the generated item for deciding between using a proper name, a definite description, or a personal pronoun. There are, however, situations in which generative decisions require information about text spans that have not yet been generated. Such situations typically arise when the generated text is subject to global constraints, i.e., constraints on the text as whole, such as its length. For example, suppose there is length

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constraint. Now, in order to decide whether it is necessary to use aggregation when generating some subspan (to stay beneath the maximum length), it is necessary to know the length of the text outside of the current subspan. This can lead to complications since at the point in time when the current span is generated, the rest of the text might not yet be available.¹ One class of global NLG constraints involves the linguistic style of a text, as regards its degree of formality, detail, partiality, and so on (Hovy 1988). Whether a text can be regarded as *moderately formal*, for instance, depends on whether formal words and patterns are chosen *moderately often*, which makes this a quintessentially global constraint. Moreover, style constraints may contradict each other. For example, if a text has to be *impartial* as well as *informal* then the first of these constraints may be accommodated by choosing a passive construction, but the second would tend to be adversely affected by that same choice. Hovy argues that these problems make top-down planning difficult because it is hard to foresee what ‘fortuitous opportunities’ will arise during later stages of NLG. Perhaps more contentiously, he argues that these problems necessitate a *monitoring* approach, which keeps constant track of the degree to which a given text span satisfies each of a number of constraints (e.g., low formality, low partiality). After generating the first n sentences of the text, the remainder of the text is generated in a way that takes the degrees of satisfaction for all the style constraints into account, for example by favouring those constraints that have been least-recently satisfied (or least-often satisfied of the text span in its totality). Monitoring is an attempt to address global constraints in an incremental fashion and may be viewed as a plausible model of spontaneous speech. It may be likened to steering a ship: when the ship is going off course, you adjust its direction. Needless to say, there is no guarantee that monitoring will result in a happy outcome, but it is a computationally

¹Compare the constraint, in daily life, that a party has to *fit into one’s living room*. This constraint can lead to interdependencies between decisions. For instance, suppose the room can contain ten visitors, and eleven invitations have already gone out. Is it wise to send out another invitation? This depends on how many of the invitations will be accepted, which can be difficult to foresee. Another, more qualitative constraint may be that the party has to be *pleasant*, and this may introduce further interdependencies (e.g., if Mr. x comes to the party then Mrs. y had better not be invited).

affordable approach to a difficult problem.

As we have seen, another example of a global constraint is the constraint to generate a text of a specified *size* (e.g., in terms of the number of words or characters used). Reiter (2000) discusses various ways in which the size of a generated text may be controlled. We already saw that for certain generation decisions it might be necessary to know the length of the remainder of the text. Based on experiments with the STOP system, Reiter observes that the size of a text is difficult to *estimate* (i.e., predict) on the basis of an abstract document plan. He argues that *revision* of texts, based on measuring the size of an actually generated text, is the way to go: when the size measure indicates that the text is too large, the least important message in the sentence plan was deleted and the text regenerated.

Revision has been claimed to be a good model of human *writing* (e.g., Hayes and Flower 1986). In some respects, size is a particularly difficult kind of global constraint, since it applies to the form rather than the content of a text, and this is why Reiter and colleagues let revision wait until a draft of the text has been generated and evaluated (i.e., after its size has been measured). In other respects, it is relatively simple, because it is one-dimensional and straightforward to define.

In this paper, we discuss a class of non-local decisions in the generation of dialogue that were first introduced in Piwek and van Deemter (2002). To be able to make these decisions in a well-motivated way, without complicating the NLG system unduly, we adopt a revision approach, which makes our system more similar to Reiter's STOP system than to Hovy's PAULINE. Like STOP, we use a revision strategy, but unlike STOP, we do not need to evaluate the textual output of the generator since, in our case, evaluation can be done on the basis of an abstract representation of the dialogue content.

Non-local decision making in Dialogue Generation

Let us define more precisely what we mean by non-local decisions in generation:

(NON-LOCAL DECISIONS IN GENERATION) Given a generator G that is producing some subspan s_a of a document D , we will call a decision by G concerning the generation of s_a *non-local* if it requires information regarding the content and/or realization of some other span s_b in D , where some or all of s_b is not included in s_a .

Given a left-to-right generation algorithm, there is no problem if s_b precedes s_a : content and form of s_b can be stored so that they are available when s_a is generated. However, if all or part of s_b succeeds s_a , (i.e., has not yet been generated), we have a problem. In the preceding section, three solutions for this problem have been exemplified: one was based on *estimating* the relevant properties of s_b , one on *revising* s_a , and one on constantly monitoring the satisfaction of the global properties that need to be satisfied.

Note that revision is a strategy which has to be treated with care. For instance, we need to make sure that never-

ending cycles of revision do not occur. Such a cycle would, for instance, occur if a particular revision operation always created circumstances which allowed it to be applied again. We return to this issue later on in this paper.

In the remainder of this paper we discuss what options are available if the text that needs to be generated is a dialogue.

Investigations into dialogue by computational linguists have typically focussed on the communication between the interlocutors that take part in the dialogue. The dialogue is taken to consist of communicative interaction between two individuals. There are, however, many situations where a dialogue fulfils a different purpose: dialogues in the theatre, on television (in drama, sitcoms, commercials, etc.) and on the radio (in radio plays, commercials, etc.) are not primarily meant as vehicles for genuine communication between the interlocutors, but rather at aiming to *affect the audience* of the dialogue (in the theatre, in front of the TV or radio). The effects are often achieved through global properties of the dialogue (the dialogue should take only a certain amount of time, should be entertaining, should teach the audience something, should make a certain point forcefully, etc.). In short, if we look at the dialogue from the perspective of an audience, global properties of the dialogue are of great importance.

The Information State approach

Firstly, let us consider the currently prevalent approach to generating dialogue. The starting point is the use of two autonomous agents, say A and B . These agents are associated with Information States (e.g., Traum et al., 1999): $IS(A)$ and $IS(B)$. The agent who holds the turn generates an utterance based on *its* Information State. This leads to an update of the Information States of both agents. Subsequently, whichever agent holds the turn in the new Information States, produces the next utterance. In most implemented systems, one of the agents is a dialogue system and the other a human user; the approach has, however, also been used for dialogue simulations involving two or more software agents (as pioneered by Power, 1979).

For our purposes, it is important to note that the agents only have access to their own Information State, and can only use this state to produce contributions. This has some repercussions when it comes to controlling global properties of dialogue. Estimation becomes more difficult if it involves a span that is to be generated by the other agent. The agent has no access to the Information State of this agent and will therefore find it more difficult to estimate what it is going to say. Furthermore, estimating one's own future utterances can become more difficult, since they may succeed and depend on utterances by the other agents. In general estimation for the purpose of coordinating the generation of the current span with not yet generated spans is more difficult/less reliable in the Information State approach.

Revision is also much more limited if the Information State approach is strictly followed. Revision is only possible within a turn. The Information State approach assumes that turns are produced according to their chronological ordering, and hence it is not possible to go back to a turn once it has been completed.

The Dialogue Scripting approach

An alternative to the Information State approach is the dialogue scripting approach. In Piwek & Van Deemter (2002) we take the main characteristic of this approach to be that it involves the creation of a dialogue (script) by one single agent, i.e., the script author. Thus, the production of the dialogue is seen as analogous to single-author text generation.

The automated generation of scripted dialogue has been pioneered by André et al. (2000). We follow André et al. (2000) in distinguishing between the creation of the dialogue text, i.e., the script and the performance of this script. Of course the Information State approach also lends itself for such a separation, but typically the authoring and performance functions are taken care of by the same agent (the interlocutors) and take place at the same time. In the scripting approach, the script for the entire dialogue is produced first. The performance of this script takes place at a later time, typically by actors who are different from the author.

There are at least two reasons why the scripting approach is better suited to creating dialogues with certain global properties than Information State approaches. Firstly, in the scripted dialogue approach the information and control resides with one author. This makes estimation more reliable; assuming that it is easier to predict one's own actions than those of another agent. Secondly, the scripting approach does not presuppose that the dialogue is created in the same temporal order in which it is to be performed. Hence it is possible to revisit spans of the dialogue and edit them.

In between traditional Information State and Scripted Dialogue approaches, *hybrid* approaches are possible. For instance, one might generate a dialogue according to the Information State approach, and then edit this draft with a single author. The techniques described in the next section are presented in the context of pure Dialogue Scripting but they remain largely valid for more hybrid set-ups.

Despite the existence of hybrid approaches it is important to keep in mind the different perspectives from which Information State and Scripted Dialogue approaches arose: the Information State approach focuses on the communication between the interlocutors in the dialogue, whereas the scripted dialogue approach focuses on the communication between the script author and the readers/audience of the dialogue; the communication between the interlocutors of the scripted dialogue is only pretended communication.

Exploring the Control of Global Dialogue Properties in NECA

In this section we discuss the control of global dialogue properties in the NECA system.² NECA generates Dialogue Scripts that can be performed by animated characters. Currently, a prototype exists –called eShowroom– for the gen-

²NECA is an EU-IST funded project which started in October 2001 and has a duration of 2.5 years. NECA stands for 'Net Environment for Embodied Emotional Conversational Agents'. The following partners are involved in the project: DFKI, IPUS (University of the Saarland), ITRI (University of Brighton), ÖFAI (University of Vienna), Freeserve and Sysis AG. Further details can be found at: <http://www.ai.univie.ac.at/NECA/>.

eration of car sales dialogues; a prototype for a second domain, Socialite, involving social chatting is under construction. Here we focus on eShowroom, which will be featured on an internet portal for car sales.

The NECA eShowroom system

The eShowroom demonstrator allows a user to browse a database of cars, select a car, select two characters and their attributes, and subsequently view an automatically generated film of a dialogue between the characters about the selected car. The eShowroom system is provided with the following information as its input:

- A database with facts about the selected car (maximum speed, horse power, fuel consumption, etc.).
- A database which correlates facts with value dimensions such as 'sportiness', 'environmental-friendliness', etc. (e.g., a high maximum speed is good for 'sportiness', high gasoline consumption is bad for the environment).
- Information about the characters:
 - Personality traits such as extroversion and agreeableness.
 - Personal preferences concerning cars (e.g., a preference for cars that are friendly for the environment).
 - Role of the character (either seller or customer).

This input is processed in a pipeline that consists of the following modules:

1. A Dialogue Planner, which produces an abstract description of the dialogue (the dialogue plan).
2. A multi-modal Natural Language Generator which specifies linguistic and non-linguistic realizations for the dialogue acts in the dialogue plan.
3. A Speech Synthesis Module, which adds information for Speech.
4. A Gesture Assignment Module, which controls the temporal coordination of gestures and speech.
5. A player, which plays the animated characters and the corresponding speech sound files.

Each step in the pipeline adds more concrete information to the dialogue plan/script until finally a player can render it (see also Krenn et al., 2002). A single XML compliant representation language, called RRL, has been developed for representing the Dialogue Script at its various stages of completion (Piwek et al., 2002).

The following is a transcript of a dialogue fragment which the system currently generates (Note that this is only the text. The system actually produces spoken dialogue accompanied by gestures of the embodied agents which perform the script):

SELLER: Hello! How can I help?
BUYER: Can you tell me something about this car?
SELLER: It is very comfortable.
SELLER: It has leather seats.
BUYER: How much does it consume?
SELLER: It consumes 8 liters per 60 miles.

BUYER: I see.
ETC.

Here, we focus on the representation of this dialogue after it has been processed by the Dialogue Planning module. The RRL dialogue script consists of four parts:

1. A representation of the initial common ground of the interlocutors. This representation provides information for the generation of referring expressions.
2. A representation of each of the participants of the dialogue. For instance, we have the following representation for the seller named Ritchie:

```
<person id="ritchie">
  <realname firstname="Ritchie"
    title="Mr" />
  <gender type="male" />
  <appearance character=
    "http://neca.sysis.at/eroom/
    msagent/ritchie_hq/
    Ritchie_Off.acf" />
  <voice name="us2">
    <prosody pitch="-20%"
      rate="-10%" />
  </voice>
  <personality
    agreeableness="0.8"
    extraversion="0.8"
    neuroticism="0.2"
    politeness="polite" />
  <domainSpecificAttr
    role="seller"
    x-position="70"
    y-position="200" />
</person>
```

3. A representation of the dialogue acts. Each act is associated with attributes, some of which are optional, specifying its type, speaker, addressees, semantic content (in terms of a discourse representation structures, Kamp & Reyle, 1993), what it is a reaction to (in terms of conversation analytical adjacency pairs) and the emotions with which it is to be expressed. The following is the representation for the dialogue act corresponding with the sentence 'It has leather seats':

```
<dialogueAct id="v_4">
  <domainSpecificAttr
    type="inform" />
  <speaker id="ritchie" />
  <addressee id="tina" />
  <semanticContent id="d_4">
    <drs id="d_3">
      <ternaryCond
        argOne="x_1"
        argThree="true"
        argTwo="leather_seats"
        id="c_4"
        pred="attribute" />
    </drs>
```

```
</semanticContent>
  <reactionTo id="v_3" />
</dialogueAct>
```

4. The fourth component of the RRL representation of the dialogue script consist of the temporal ordering of the dialogue acts:

```
<temporalOrdering>
  <sequence>
    <act id="v_1" />
    <act id="v_2" />
    <act id="v_3" />
    <act id="v_4" />
    .
    .
    .
  </sequence>
</temporalOrdering>
```

Enforcing global constraints in dialogue

Here we want to examine how to adapt the system so that it can take global constraints into account. We have seen in the preceding section that the *Dialogue Scripting* approach is best suited for the control of global dialogue properties. The NECA system is based on Dialogue Scripting: each module in the pipeline operates as a single author/editor which creates/elaborates the Dialogue Script. Within the Dialogue Scripting approach various methods for controlling global properties can be employed. Earlier on, we discussed monitoring, estimation and revision as approaches that have been employed in text generation. For the purpose of this paper, we limit our attention to the revision approach.

There are a number of reasons for this choice. Firstly, monitoring is tailored to left-to-right processing, whereas the dialogue scripting approach is not constrained in this way. Moreover, monitoring can only work well if the number of decisions relating to each constraint is very large, since this gives the system many opportunities for 'changing course'. But even if a single-pass monitoring approach *could* work well at the level of dialogue, it would tend to complicate the design and maintainance of the system (cf. Callaway & Lester 1997, Reiter 2000, Robin & McKeown 1996).³ Having a separate revision module also allows for a more straightforward division of labour between multiple system developers. (In NECA, for example, the dialogue planner and the revision system are developed at different sites.)

Furthermore, Reiter (2000) argues that revision compares favourably with other techniques for satisfying size constraints (a specific type of global constraint) in text generation. He compares revision with heuristic size estimators (for predicting the size of the text on the basis of the message to be conveyed) and multiple solution pipelines. Robin and McKeown (1996) discuss the implementation of revision in a summarization system for quantitative data (STREAK).

³We could, for instance, have included the aggregation and insertion operations (see below) directly in our dialogue manager, but this would have complicated the dialogue planner rules.

They carried out two evaluations which they argue show that their revision-based approach covers a significantly larger amount of the structures found in their corpus than a traditional single-pass generation model. Additionally, they claim that their evaluation shows that it is easier to extend the revision-based approach to new data.

Our approach to revision differs from other approaches. Firstly, our revisions are carried out on the abstract dialogue plan, before linguistic realization. Although Callaway & Lester also carry out their revision operations on abstract representations of sentences, these are obtained by first generating concrete sentences and then abstracting again over irrelevant details. Instead of first fully generating and then abstracting, we follow an approach of partial generation. Secondly, Reiter and Callaway & Lester focus on a single type of constraint. In this respect, our work is more similar to that of Hovy, where different types of potentially conflicting constraints are considered. To our knowledge, we are the first to propose revision operations on *dialogue* structure as opposed to discourse or sentence structure. Ultimately, of course, these different types of revision ought to be addressed through one common approach.

Two constraints and a revision problem

To illustrate the issues, let us consider two global constraints on dialogue:

- Number of turns in the dialog (TURNS): maximal (MAX) or minimal (MIN)
- Degree of Emphasis (EMPH): maximal (MAX) or min (MIN)

For the moment, we keep the constraints as simple as possible and assume that they can only take extreme values (MAX or MIN).

Furthermore, we introduce two revision operations on the output of the dialogue planner:

- ADJACENCY PAIR AGGREGATION (AGGR)

Operation: Given the adjacency pairs $A = (A_1, A_2)$ and $B = (B_1, B_2)$ in the input, create $A+B = (A_1+B_1, A_2+B_2)$.

Precondition: A and B are about the same value dimension.

Example: $A =$ (Does it have airbags? Yes),
 $B =$ (Does it have ABS? Yes),
 $A+B =$ (Does it have airbags and ABS? Yes)

Comment: The shared value dimension is *security*.

- ADJACENCY PAIR INSERTION (INSERT)

Operation: Given adjacency pair $A = (A_1, A_2)$ in the input, 1. create adjacency pair $B = (B_1, B_2)$ which is a clarificatory subdialogue about the information exchanged in A and 2. insert B after A , resulting in $(AB) = (A_1, A_2)(B_1, B_2)$.

Precondition: The information exchanged in A is marked for emphasis.

Example: $A =$ (Does it have leather seats? Yes). Assume that *comfort* is positively correlated with having leather seats and that the user has indicated that the customer prefers comfortable cars. On the basis of this, the information exchanged in A is marked for emphasis. The text after revision is: $(AB) =$ Does it have leather seats? Yes. Real leather? Yes, genuine leather seats.

Comment: Piwek & Van Deemter (2002) contains examples of how human authors of scripted dialogue appear to use sub-dialogues for emphasis.

In the definitions of the two operations we use the notion of an *adjacency pair* which is common in Conversation Analysis. The idea is that the first and second part of the pair are connected by the relation of conditional relevance (e.g., a pair consisting of a question and an answer): ‘When one utterance (A) is conditionally relevant to another (S), then the occurrence of S provides for the relevance of the occurrence of A ’ (Schegloff, 1972:76).

Let us now describe our revision problem. We have an initial dialogue plan dp_1 , produced by the dialogue planner. Before it is passed on to the multi-modal natural language generator we want to apply the revision operations AGGR and INSERT in such a way that the resulting dialogue plan dp_2 optimally satisfies the constraints for TURN and EMPH. In total, there are four possible constraint settings:

1. TURN = MAX and EMPH = MAX.
2. TURN = MAX and EMPH = MIN.
3. TURN = MIN and EMPH = MIN.
4. TURN = MIN and EMPH = MAX.

Sequential revision

Let us look at two alternative ways in which these constraint settings might be satisfied. The first is simple-minded but efficient: First, one operation is applied as often as needed and then the same is done for the other operation. We assume that insertion correlates with EMPH and aggregation correlates with TURN. If a constraint is set to MAX, the operation is performed as often as possible; if the constraint is set to MIN, the operation is not applied at all. Note that this procedure will always terminate, given that our initial dialogue plan contains only a finite number of pieces of information that are marked for emphasis and there is only a finite number of adjacency pairs which share a value dimension. Hence the preconditions of the operations can only be satisfied a finite number of times.

There are, however, complications, since constraints may be interdependent. One type of problem obtains when one operation affects (i.e. creates or destroys) the preconditions for another. Suppose, for example, our setting is (TURN = MAX, EMPH = MAX), while aggregation is performed before insertion. In this case, a less than maximal number of aggregations would result, since insertion can introduce new candidates for aggregation. This type of problem can usually be finessed by finding an ‘optimal’ ordering between operations: if insertion precedes aggregation, both constraints of

our example situation can be satisfied. Unfortunately, however, there is another type of problem which cannot be finessed so easily. Suppose, for example, our setting is (TURN = MIN, EMPH = MAX), and observe that insertion positively affects the number of turns as well as the degree of emphasis, affecting the two constraints (TURN = MIN, EMPH = MAX) in opposite ways. In such a case it is unclear what the best strategy is: the algorithm might either maximize the number of insertions, trying to maximize emphasis, or minimize them, trying to minimize the number of turns. To tackle problems of both kinds, an approach is needed that is able to make *trade-offs* between conflicting constraints.

A ‘Generate and Test’ approach

To tackle both these problems, we propose a ‘generate and test’ approach to the revision problem. The algorithm proceeds as follows:

1. We use a conventional topdown planner to produce a single dialogue plan dp_{start} .
2. Next, we generate all possible plans that can be obtained by applying the operations INSERT and AGGR zero or more times, in any order, to dp_{start} . Let us call this *set* of all possible output plans DP_{out} .
3. Each member of DP_{out} is assigned a score for the TURN and EMPH constraints. Each dialogue plan $dp \in DP_{out}$ is characterized as a tuple consisting of the TURN and EMPH scores $\langle S_T, S_E \rangle$. The TURN score S_T depends on the number of turns of the dialogue plan. The EMPH score S_E depends on the number of emphasis subdialogues in the dialogue plan that were added during revision. We assume that our scores are normalized, so they each occupy a value on the interval [0-100], i.e., satisfaction of the constraint from 0% to 100%. 100% means that there is no alternative dp which does better.
4. Finally, on the basis of the scores assigned to the plans in DP_{out} and according to some arbitration plan, we select an optimal outcome or set of optimal outcomes, i.e., a unique solution or a set of solutions.

At this point, one might ask how we decide which operations are included in the conventional topdown planner and which ones are deemed revision operations. To answer this question, it will be useful to elaborate a bit on our underlying assumptions about dialogue.

In classical Discourse Theory (e.g., Stenström, 1994) conversations typically consist of three distinguishable phases: an opening, a body and a closing. each of which has a specific purpose. According to for, instance, Clark (1996) individual dialogue acts belong to different tracks depending on how directly they contribute to the purpose of the dialogue phase in which they occur. On track 1 we have dialogue acts which are intended to immediately contribute to furthering this purpose, for instance, the buyer’s asking for the price of the car to the seller or the buyer’s introducing him- or herself to the seller.⁴ Metacommunication about the

⁴In our tentative view, greetings occur at the level of track 1, since they directly further the purpose of the opening and are, there-

fore, distinct from the metacommunication which takes place on track 2. This includes monitoring the success of the communication, attempting to fix communication problems, etc.

For our purposes, the distinction between acts on track 1 and 2 is a useful one, since acts on track 2 can be viewed as mere decorations of the acts which further the purpose of the conversation on track 1. For example, if we omit the utterances on track 2 the remaining dialogue script still makes sense (cf. Piwek & Van Deemter, 2002), whereas removing utterances from track 1 does not have the same effect. Consider, for instance, the following exchange:

1. BUYER: How much does the car cost?
2. SELLER: 15.000 Euro.
3. BUYER: 15.000?
4. SELLER: Yes, only 15.000.

The acts on track 1 (1. and 2.) make sense on their own, whereas those on track 2 (3. and 4.) do not. For this reason, acts on track 1 are dealt with by the dialogue planner, while acts on track 2 are inserted at the revision stage, by means of the operation INSERT.

The operation AGGR is an instance of an aggregation operation on the dialogue level. Aggregation operations are typically dealt with as involving revision: two or more structures are merged/ revised into one new structure. Our AGGR allows us to reorganize the location of dialogue acts. It does not add or remove any dialogue acts. The precondition on AGGR, which stipulates that only dialogue acts which deal with the same value dimension can be aggregated, guards against erratic reorganizations of the dialogue, destroying smooth shifts from one topic (value dimension) to another.⁵

A second issue which the current sketch for an algorithm raises is that of the choice of an ‘arbitration plan’ for selecting the solution or set of solutions from DP_{out} . Fortunately, this is a well-known problem in decision theory and more specifically game theory. One would like an arbitration plan to satisfy certain criteria which define a fair balancing of different constraints. One set of such criteria is due to John Nash, who proposed that a solution should satisfy the following four axioms (Nash, 1950):

1. LINEAR INVARIANCE: If one transforms the scores for either constraint by a positive linear function, then the solution should be subject to the same transformation. This axiom derives from the fact that the score/utility functions in game theory are normally taken to be an interval scale. These are invariant only under positive linear transformations.
2. SYMMETRY: If for each outcome associated with a pair of scores $\langle x, y \rangle$, there is another outcome $\langle y, x \rangle$, then the solution should consist of a pair of identical scores $\langle z, z \rangle$. In words, constraints are treated as equals with respect to each other.

fore, distinct from the metacommunication which takes place on track 2. Alternative views would be equally easy to model.

⁵More generally, the generation of texts with smooth topic shifts can be seen as a constraint satisfaction problem. See, for instance, Kibble & Power (2000).

3. INDEPENDENCE OF IRRELEVANT ALTERNATIVES: Suppose we have two different outcome sets A and B . Assume also that $A \subset B$. If the solution for B is a member of A , then this solution should also be a solution for A . In words, the unavailability of non-solution outcomes should not influence the final solution.
4. PARETO OPTIMALLY: The solution should be Pareto Optimal. A pair $\langle S_T, S_E \rangle \in DP_{out}$ is Pareto Optimal iff it is impossible to find another pair $\langle S'_T, S'_E \rangle \in DP_{out}$ such that:
- $S'_T = S_T$ and $S'_E > S_E$ or
 - $S'_E = S_E$ and $S'_T > S_T$ or
 - $S'_E > S_E$ and $S'_T > S_T$.

For our purpose, the notion of Pareto Optimality is particularly interesting. A pair is Pareto Optimal if and only if it is impossible to improve one of its elements without making the other element worse off. Unfortunately, Pareto Optimality does not help us to identify a unique solution: For example, if DP_{out} contains only two pairs: $dp_1 = \langle 100, 10 \rangle$ and $dp_2 = \langle 50, 50 \rangle$ then both pairs are Pareto Optimal.

Nash came up with an arbitration plan which satisfies not only Pareto Optimality, but all four of the proposed axioms. The idea is that by satisfying the four axioms, Nash's arbitration plan provides a 'fair' solution to the problem of maximizing the degree to which both (in general: all) constraints are satisfied, that is, a solution that treats the two constraints evenhandedly. According to the Nash arbitration plan, the optimal solution is the solution $\langle S_T, S_E \rangle$ with the highest value for $S_T \times S_E$. This plan causes dp_2 to win, which is a desirable outcome, in our opinion.

The Nash plan is guaranteed to choose a solution that is Pareto Optimal. The same is true for a plan that maximizes the sum instead of the product of the scores, but this would fail to punish a treatment that favoured one constraint over the other, as in the case of the $dp_1 = \langle 100, 10 \rangle$ and $dp_2 = \langle 50, 50 \rangle$.

Conclusions

We have discussed various existing methods for controlling global properties of generated text (such as length and style). Having done this, we have focused on generated *dialogue*, offering a number of arguments in favour of the *Scripted Dialogue* approach. Building on observations in the literature, we went on to make a case for *revision* approaches to controlling global properties of scripted dialogue. More specifically, we have sketched the potential for a revision approach to dialogue generation in the NECA system. In our discussion of NECA, we have outlined a new 'generate and test' approach that would put well-known techniques from decision theory and game theory to a novel use, thereby exemplifying a recent trend in formal and computational linguistics (Rubinstein 2000).

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