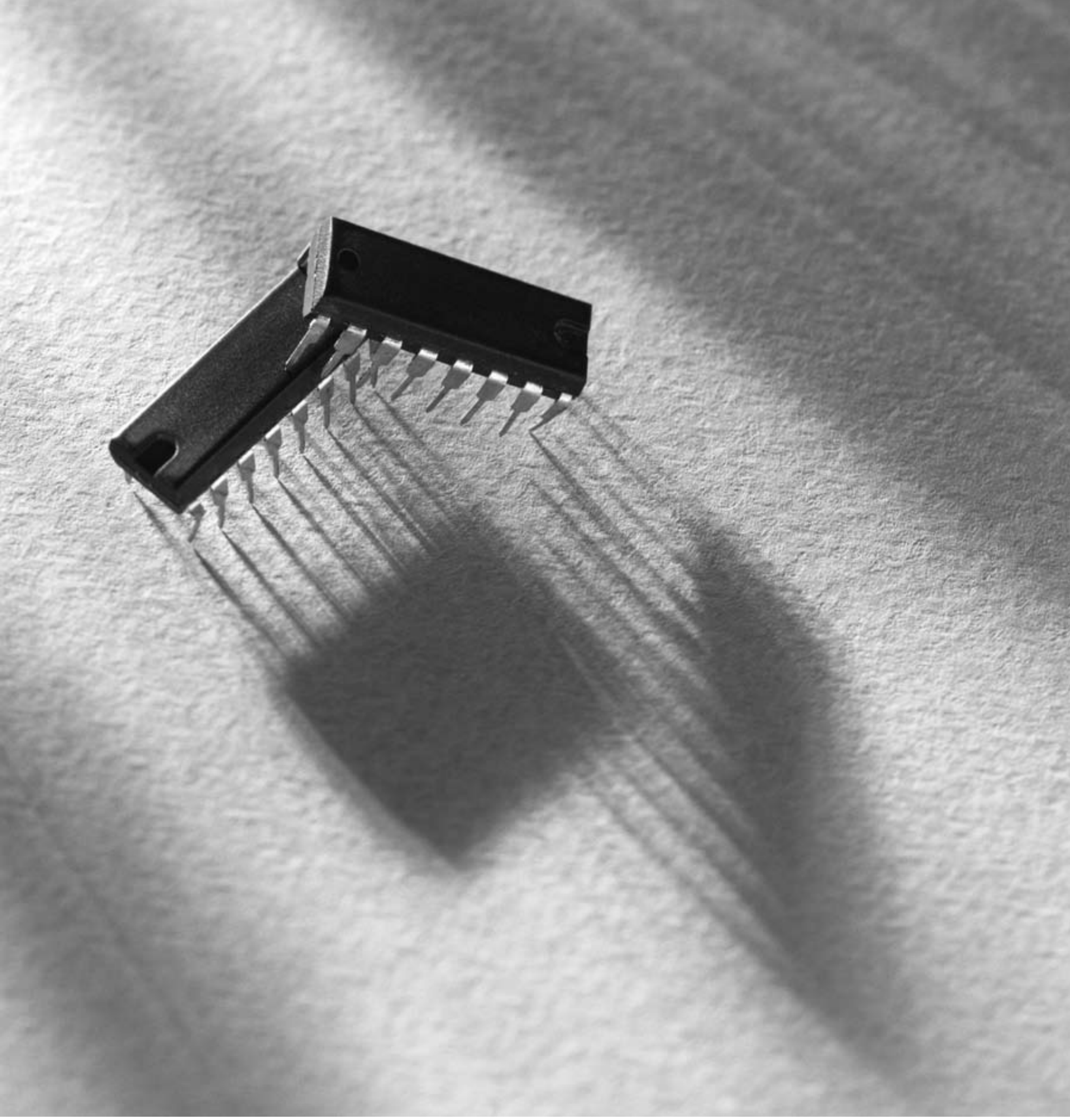

Computational Use of Informal Logic Dialogue Games

Abstract

The purpose of this paper is to move forward the interplay between research within informal logic on dialogue game models, and research on their computational utilisation. In particular, we consider the current use of dialogue games in human computer interaction and agent communication, and the dialogue systems we have developed recently. Major barriers in the computational use of dialogue games are outlined and means of overcoming them discussed.

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Computational Use of Informal Logic Dialogue Games

Introduction

The field of informal logic (IL) can be seen as the attempt to develop tools that can analyse and evaluate the reasoning and arguments that occur in contexts such as political debate and legal proceedings (e.g. Fisher 2000, Johnson and Blair 2000, Walton 1989b). Johnson and Blair (2000) identify fourteen recent areas of research in IL and Groarke (2002) suggests that three approaches to informal logic can be characterised, concerned with fallacy theory, rhetoric and dialogue. The last of these is often referred to as "dialectics" (e.g. Walton 1998). A common approach within dialectics is to construct *dialogue games* (e.g. Hamblin 1971, Mackenzie 1979, Walton and Krabbe 1995). A dialogue game can be seen as a prescriptive set of rules, regulating the participants as they make moves in the dialogues. These rules legislate as to permissible sequences of moves, and also as to the effect of moves on participants' "commitment stores", conceived as records of statements made or accepted. Such dialogue games have received much recent interest from the Artificial Intelligence (AI) and Human Computer Interaction (HCI) community, and much of the current paper will be concerned with them.

The remainder of this paper is organised as follows. We start with a brief overview of the current use of dialogue games in the area of human computer interaction and agent communication. We then report the computer systems we have developed in facilitating human computer argumentation and inter-agent dialogue simulation. We finally discuss a number of important barriers that need to be overcome if the potential of dialogue is to be fulfilled.

Current Use of Dialogue Games

One major use concerns the mediation of argument. Mediation in a legal context has been particularly important (cf. Bench-Capon 2000, Carbogim et al. 2000). Gordon (1994), for example, has developed a model of civil pleading, the "pleading games", where plaintiff and defendant confront each other. Bench-Capon (1998) argues that "the rule governed environment of a dialogue game can provide the necessary structured context for a quasi-courtroom argument", and develops "TDG", a dialogue game based on Toulmin's argument schema, for this purpose. This game can be used to mediate discussions between human participants and seeks to ensure that the argument resulting from the dialogue has an appropriate (Toulmin-based) structure (Bench-Capon 1998). Similarly, the dialectical argumentation system "DART" has been used to model legal reasoning and argumentation (Freeman and Farley 1996). The model captures arguments both as supporting explanations - connecting claims with appropriate supporting data - and as dialectical process - "alternating series of moves made by opposing sides for and against a given claim" (p. 166, cf. Prakken and Sartor (1996)). The DART model incorporates a "burden of proof" concept, enabling it to support decisions ranging from "sceptical" to "credulous". Similarly, Prakken and Sartor (1996) develop a dialogue game to assess conflicting arguments in legal reasoning. Again, Leenes et al. (1994) argue for using a dialogue game model of legal justification, and argue that dialogue games requiring students to construct legal arguments provide a useful means of teaching legal skills. Argument mediation in an educational context is also important. Pilkington et al. (1992), for example, have used dialogue games to implement a computer-mediated argumentation system called DIALAB, and in a similar vein, Burton et al. (2000) use dialogue games to implement CLARISSA, a computer modelling laboratory for investigating collaboration. Pilkington (1998, cf. Pilkington and Parker-Jones 1996) demonstrates enhancements to a medical simulation-based learning system brought about partly by the adoption of dialogue games. Two types of dialogue game are identified, an inquiry dialogue with asymmetrical participant roles and a more collaborative game generating cognitive conflict and reflection. Ravenscroft and Pilkington (2000) use a dialogue game framework to facilitate a "structured and constrained dialectic" which in turn aids the student in enhancing explanatory domain models. Their dialogue game framework is able to simulate the tutorial tactics of an expert tutor within a "collaborative argumentation" approach to "learning as knowledge refinement". Thus the game involves asymmetrical participant roles, the computer being a "facilitating tutor" and the student the "explainer". The framework has been implemented in a prototype system "CoLLeGE" (Computer based Lab for Language Games in Education). An empirical study has shown the effectiveness of the dialogue game framework (Ravenscroft and Matheson 2002).

Dialogue games have also been increasingly used in human computer dialogue. Vreeswijk (1995) for example has designed "IACAS", an interactive argumentation system enabling disputes between a user and the computer. Mackenzie's (1979) DC system has been used for competitive debate, and its applicability has been tested in educational discourse contexts (Moore 1993, 2000; Moore and Hobbs 1996). Grasso et al. (2000) outline a system they have built, designed to change the attitudes of its users in the domain of health promotion. The system is based on informal argumentation theories (Walton 1989b), on the grounds that the theory is able to capture "every day arguments and the way they are used to change opinions and values" (p 1080). The system's dialogue manager can be armed with a differing range of dialogue games according to prevailing circumstances. Dialogue games have also been proposed as enhancements to intelligent help systems (Moore and Hobbs 1996, Pilkington 1992) and expert system explanation generators (Moore and Hobbs 1996, Bench-Capon et al. 1991). Walton (1998) describes "Negotiator Pro", an expert system, built on dialectical principles, that offers advice on the conduct of bargaining negotiations and elsewhere Walton (2000) argues that "the growing field of expert systems provides a natural application for dialogue theory … sequences of questions and replies – dialogue in short – is a vitally important aspect of the implementation of any expert system" (p 330).

There are also several proposals for dialogue game protocols that can be found in the agent literature. Amgoud et al. (2000) for example modify Mackenzie's (1979) DC game to enable it to handle persuasion, inquiry, information-seeking and negotiation dialogue. Dignum et al. (2001) adopt Walton and Krabbe's (1995) RPD for rigorous persuasion dialogues to enable agents to form teams and to agree joint intentions. Hitchcock et al. (2001) present a dialogue game protocol for deliberation dialogues, drawing on a theory of deliberative argument from the philosophy of argumentation. McBurney and Parsons (2001) design a dialogue game protocol for agents engaged in an inquiry dialogue. A negotiation dialogue protocol for potential online buyers and sellers is proposed in (McBurney et al. 2003). This protocol enables the participants to express uncertain beliefs about claims and to resolve these on the basis of the arguments for and against the claims presented in the dialogue. Atkinson et al. (2005) propose a dialogue game protocol for multi-agent argument over proposals for action, and have constructed a system (PARMA) operationalising the protocol to allow two human participants to argue with each other. They are preparing to extend PARMA for use in BDI agents (Atkinson 2005).

Our own work concerning computational utilisation of dialogue games has three aspects: first, using dialogue game as the underlying dialogue model for the development of a human-computer debating system; secondly, constructing an agent-based dialogue simulation system as a test bed to evaluate the dialogue game models; and thirdly, using the argument game and an abstract argument system to develop a computer game for human-human, human-agent and agent-agent interaction. Each is outlined in the following sections.

Human-Computer Debating System

The primary motivation of the development of a human computer debating system is that the system is expected to be used to help develop students' debating and reasoning skills and domain knowledge. We have used "DE", a dialogue game developed based on Mackenzie's (1979) "DC", as the underlying dialogue model. The detailed specification of the "DE" system can be seen from (Yuan et al. 2003). To enable the computer to act as a dialogue participant and generate high quality dialogue contributions, a set of strategic heuristics has been developed and documented in (Yuan 2004).

Our approach is to use the DE dialogue model and the proposed strategy as the basis for a human-computer debate system. A fully functional system has been built, using the Java programming language, and the current version is deployed on the internet (*http://staff.unak.is/not/yuan/game/debate/system.htm*). The system asks the user his opinion on the controversial issue of capital punishment, adopts the opposite position and engages the user in debate on the issue. The computer can adopt either a proponent or an opponent role. That is, if the user chooses to support the view of "capital punishment is acceptable", the computer will adopt the opposite view "capital punishment is not acceptable", and vice versa. The system then engages the user in debate on the topic of capital punishment, given these initial positions on the issue. The system interface and an example of the dialogue interaction can be seen in figure 1.

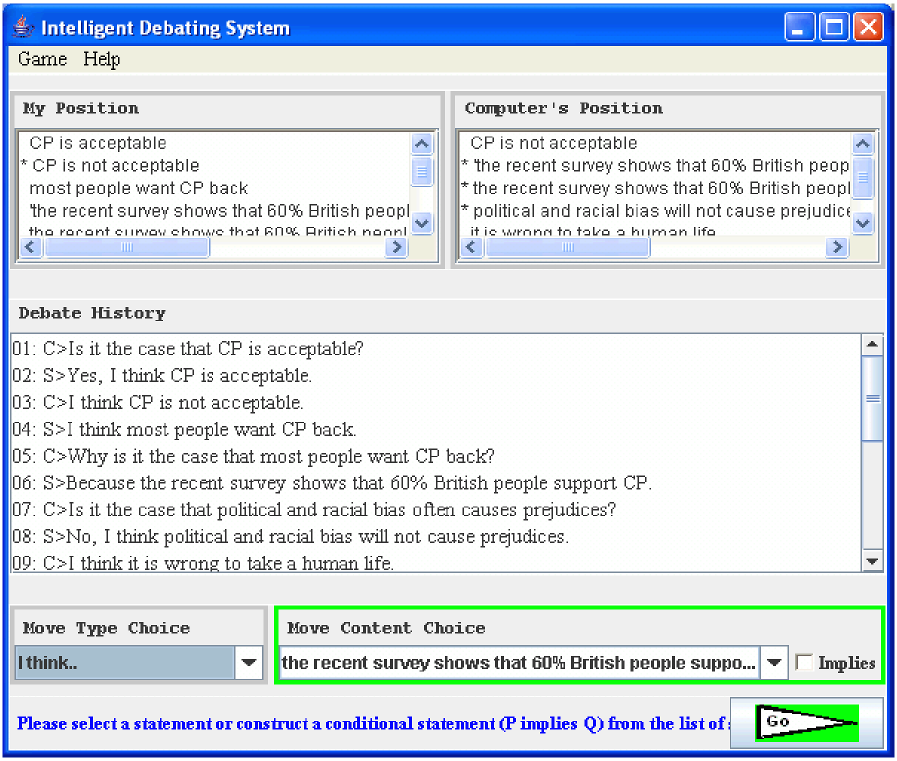

Figure 1 Human-Computer Debating System User Interface

A preliminary usability evaluation of the human computer debating prototype has been carried out via expert walkthroughs and documented in (Yuan 2004). A subsequent user based evaluation of the debating system has also been carried out and documented in (Ævarsson 2006). Essentially, the expert evaluations give positive evidence concerning the usability of the system in general, and of the DE dialogue model and the proposed strategy in particular. Turning to the user based evaluation, all participants successfully conducted debate with the system without difficulties. They agreed that the system is intelligent and a worthy debate component and can be used to help them practise argumentation, although some participants said they would like to see the system more aggressive and more attacking. The participants said they enjoyed playing the game, and they particularly liked the nondeterministic nature of the system's dialogue contributions and would like to play the game again were it available as an Internet game. The evaluation also suggested some weaknesses of the strategy and the user interface. Current work involves amending the system to cater for these concerns.

An Agent-Based Dialogue Simulation System

An agent-based dialogue simulation system has also been developed with the intention of using it to facilitate the evaluation of dialogue games and dialogue strategies. This idea follows Maudet and Moore's (2001) argument that the dialogue models and strategies can usefully be tested via generation of dialogue by the computer itself. Conversational simulation is also stressed by Amgoud and Maudet (2000) to be an important means of getting empirical results about dialogue models and their behaviours. A convenient approach, we argue, is to allow two computational agents to run with a proposed model and/or dialogue strategies in dialogue with each other and study the result, since there is then less human involvement and it is easy to control the experimental variables. An agent-based system has been built using the Java programming language. The implementation details can be found in (Yuan et al. 2003). An example system interface can be seen in figure 2.

We have used computational agents to generate dialogue transcripts, and this has facilitated the evaluation of the dialectical system DC and motivated the development of a further dialogue game system DE (Yuan et al.

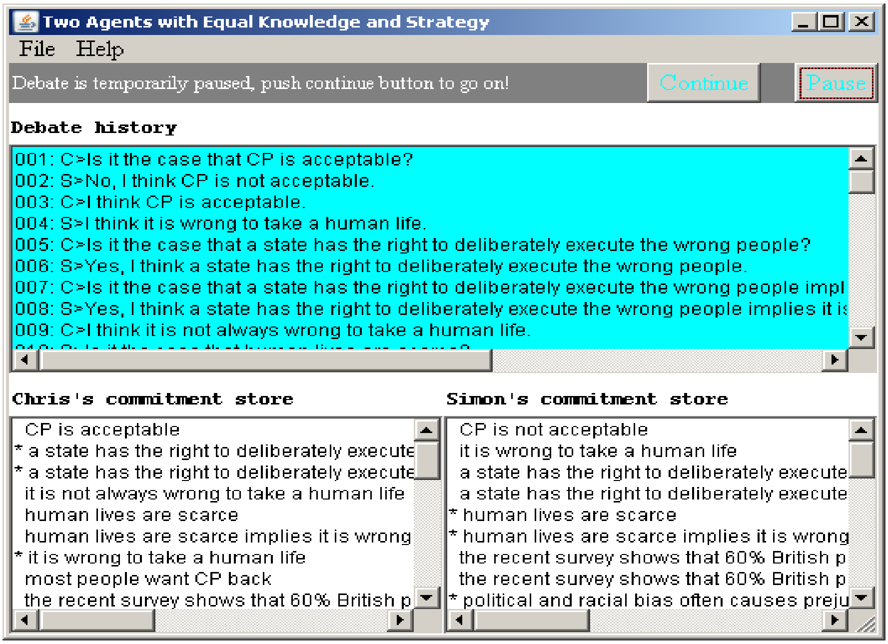

Figure 2 Agents Dialogue Simulation System Interface

2003). We have also used the agent system to assess the dialogue strategy we adopt in our debating system (Yuan 2004). The current system is developed in a component fashion which enables researchers to replace three variables: the dialogue model, the strategy and knowledge base component. The current version is available on the internet (*http://staff.unak.is/not/yuan/game/simulation/dialogueSimulationSystem.htm*). Our current work involves simplifying the system so that dialogue game researchers can easily use it to assess their dialogue models and strategies.

A Computer Game for Abstract Argumentation

Our work also involves using the abstract species of argument (Dung 1995) to construct a computer game to enable human-human, agent-agent and human-agent interaction. The game is expected to be entertaining and at the same time to be used to educational advantage - to develop students' planning skills. We adopt the argument game presented in Wooldridge (2002 p. 153-154) for reasons of simplicity. Essentially, the game enables two dialogue participants to take turns producing counter arguments to the 'most recent' argument advanced by their opponent. Repeated argument is not allowed. The winner is the one who makes the last move.

A fully functional system has been built, using the XML and Java programming languages, and deployed on the internet (*http://staff.unak.is/not/yuan/game/index.php*). Full details can be found from (Yuan et al. 2007). The game currently has three levels relating to the complexity of the argumentation system. A user can select his/her preferred level to play the game. In addition, the system is designed to enable the user to select his/her opponent. There are three choices for this: another human player, a random agent or a smart agent. A random agent is the one making a move by randomly picking up a legally available argument. A smart agent has been given strategies to select the best possible arguments in order to win the game. Rather than being a game player, the user can also set up two software agents and observe them playing the game.

An example game, with a user playing with a software agent can be seen in figure 3. The user made the first move *p*, the agent made the second move *a*, although it had other available options *c*, *w*, *o*, in attacking *p*. In the third turn, the user made the only available move *o* in attacking *a*. The game continued until the user made the argument *m*. The software agent in this situation could not locate any further arguments attacking *m*, the system therefore proclaims the user the winner.

An initial usability evaluation of the system has been conducted. The evaluation suggests that the game is both challenging and entertaining, with a low learning curve, and that the proposed strategy for the smart agent performs much better than the random strategy, and they both seem to encourage human users to play with a software agent. Some participants were confused with the attacking relations in the beginning, e.g. whether $a \rightarrow b$ refers to *a* attacks *b* or *b* attacks *a*. Current work involves a refinement of the current system.

The computer game can be extended for other use in at least two ways. First, it can be expanded to enable hyperlinks from the abstract arguments to concrete arguments in some particular domain, and thus enable the dialogue participants to exchange concrete arguments as well as the current abstract ones. Secondly, the system can also be extended for use in agent systems, e.g. by providing additional functionality to calculate and display preferred extensions of argument systems.

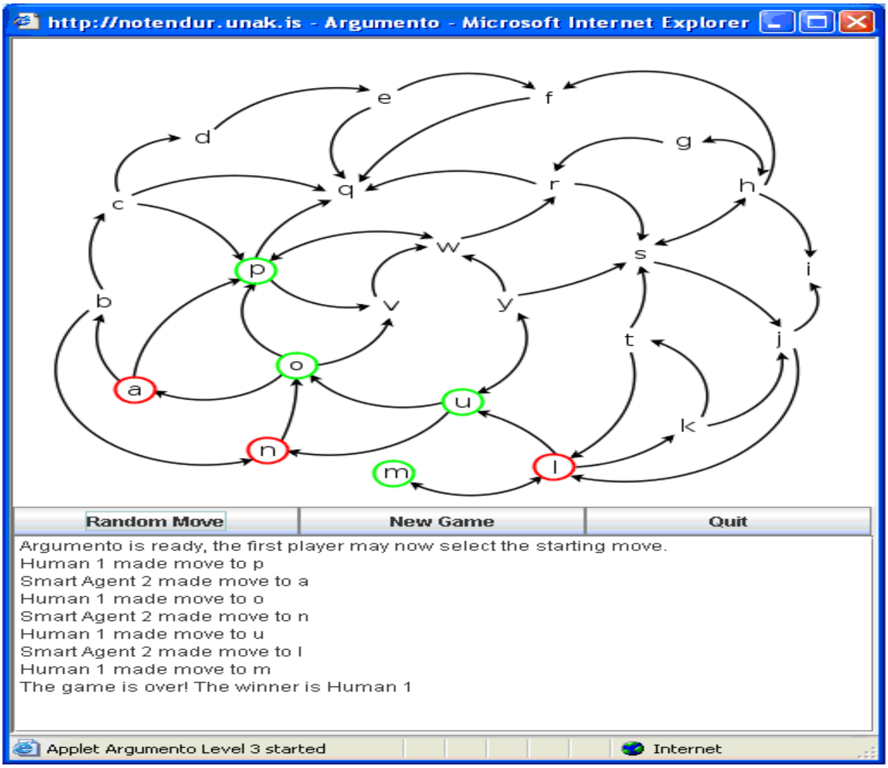

Figure 3. An example of abstract argumentation game interface

Major Barriers

Thus far we have shown that there is increasing evidence of the use of dialogue games within computer dialogue systems and outlined our work in this area. However, there are, we argue, four potential barriers to the use of dialogue games in this role. For the remainder of this paper we examine these barriers in turn and, by discussing current research work, try to defend the continuing investigation of computational use of dialogue games.

Barrier 1 - Lack of flexibility

Since the games purport to be normative, prescriptive models of dialogue, they tend to represent idealised rather than everyday interactions (Walton 1998) and their prescriptions may impose an unduly high cognitive load on the would-be user. This issue is particularly important in a HCI context. There is some evidence, however, that mastery of the systems' stipulations is not unduly problematic (Moore and Hobbs 1996), particularly in a computational environment (Ravenscroft and Pilkington 2000; Yuan 2004).

A further concern is that such dialogues as can be generated via a dialogue game may be "rather stilted" (e.g. Bench-Capon 1998). For example, the dialogue game systems tend to restrict questions to the yes/no variety, and to insist that they be answered directly, and this may not always represent a reasonable approach to dialogue (Walton 1998). It seems likely, however, that many such weaknesses can be overcome in a computational environment. For example, arranging for key points of the computer's dialogue contribution to be represented as hypermedia nodes (Moore 2000), enables a user to clarify points from the computer's dialogue contributions, and thus to by-pass the restriction to yes/no questions. More generally, we argue (Maudet and Moore 2001) that enriching the dialogue with varying forms of media may surmount the problem of the potentially stilted nature of the dialogue.

In any event, such problems represent weaknesses with the dialogue models *per se*, rather than with their computational utilisation. As such, they can perhaps be overcome by suitable amendments to the models, for example we have used Mackenzie's DC system as the basis and developed DE (Yuan et al. 2003). Similarly, Loui details four game systems "exhibiting a range of considerations that have been raised in the design of defeasible reasoning systems" (Loui 1998 p. 22) and Ravenscroft and Pilkington (2000) discuss "adapting and extending some of its [DC's] moves to facilitate a richer and more flexible dialogue game" (p. 281). Ravenscroft and Pilkington (2000 p. 294) also talk of ".. providing future designers with a toolkit for investigating dialogue games to suit their own applications", and our dialogue simulation system outlined in section 4, and Prakken's (2001) general framework which can be used to generate specific dialogue protocols represent attempts to provide such a toolkit. Indeed, computational use of the models can be expected to help clarify the models themselves (Krabbe 2000), so that research in dialectics and in computation works to each others' mutual advantage (Maudet and Moore 2001, Hitchcock 2000).

A further approach, complementary to that of extending the dialogue games, is to provide for the incorporation of multiple dialogue game types into a single dialogue. Walton suggests that "the problem of how to formally represent functional embeddings of dialogues has not yet been solved. It is by no means a purely philosophical problem, and also represents a real problem for the development of computer dialogue systems" (Walton 2000 p. 338). However, considerable efforts have been devoted to model diverse dialogue types as games within a larger structure (e.g. Maudet and Moore 2001, Reed 1998, McBurney and Parsons 2002). The extended dialogues are seen as potentially consisting of sequences, embeddings and other combinations of dialogue games, which can be distinguished from each other via topic (different games of the same type), aim (different game types, same topic) or both (different game types and different topics).

Barrier 2 - Computer strategy

The issue of computational strategy within a dialogue game is fundamentally important. For dialogue games tend to be very sparse (Moore and Hobbs 1996). Whilst this is advantageous in some regards from the computational point of view, the cost of the models' simplicity is a reliance on the strategic wisdom of the participants, for example to maintain relevance. An understanding of suitable strategies adopted becomes therefore vital. The computer will also follow the model's slender rule set, and it will be equally reliant, therefore, upon appropriate strategic wisdom. Indeed, the ability to capture this wisdom could be seen as the crucial aspect of computational use of dialogue games.

It should be noted that any link to the discourse semantics forged via such strategic decisions is largely an extra-game consideration: all the dialogue game model does is legitimise a set of move types given the prevailing circumstances, and occasionally give some indication of the semantic possibilities. One might think that the model would indicate what is legally available, a strategic choice would be made from this range, and the choice would then be 'filled up' with semantic content. Such a view would be too simple, however, for the strategic decision is likely to rely heavily on the available content, and a strategic decision may be needed between alternative contenders for the content (different supporting evidence, for example). In any computerised system, some interplay between strategic and semantic components is therefore needed.

As a result, considerable research effort has been devoted to the development of suitable computational strategies. In our human computer debating system, for example, we argue that there are three levels of decisions to consider (Moore and Hobbs 1996, Yuan 2004). At *level 1* the issue is whether to retain or change the current focus. At *level 2* the decision for the computer is whether to "demolish" the user's position, or to seek to "build" its own position. In a similar manner, Freeman and Farley (1996) picture side-1 building support for its claim, and side-2 seeking to refute side-1's arguments via "undercutting" or "rebutting". At *level 3* the decision involves which *method* to adopt in fulfilment of the objective set at levels 1 and 2. For dialogue types other than debate, other strategies may be appropriate. Grasso et al. (2000), for example, adopt, for their nutritional advice-giving system, schemas derived from Perelman and Olbrechts-Tyteca's (1969) "New Rhetoric", and Ravenscroft and Pilkington (2000) have " a repertoire of legitimate tactics available for addressing common conceptual difficulties" (p 283). Amgoud and Maudet (2000) suggest "meta-preferences", such as "choose the smallest argument", to drive the choice of move, and Freeman and Farley (1996) delineate ordering heuristics as guidelines for selecting argument moves.

An extra-game level of strategy is also needed to cope with dialogues comprising more than one game (cf. Walton and Krabbe's notion (1995) of "subdialogues"). This additional level of strategy is concerned with the issue of whether to retain or change the on-going game. We can distinguish two kinds of computational behaviour. As a *reactive agent* the computer merely adopts a stance with regard to incoming game bids. The computer does not plan for or bid new games. Nevertheless, it recognises games when they are bid by a partner and makes a strategic decision whether to accept that bid or attempt to continue the current game. As a *deliberative agent* the computer has the ability to plan games. In other words, it attempts to bid and enter into games. A computational agent able to handle these structures may need to process "mental" attitudes, such as intention or desires, in addition to the "commitments" of our current prototypes, e.g. via the Belief-Desire-Intention (BDI) architecture.

Barrier 3 - Group dialogues

Thus far we have implicitly assumed that all dialogue games involve two participants. An important development of the work is to relax this assumption and enable multiple participants. This is an important issue in current HCI, given the importance of group work in education (e.g. Cumming and

McDougall 2000) and the growing interest in computer supported collaborative learning (CSCL) in general (Hoadley 1999, Steeples et al. 1996, Stahl 2006) and computer supported collaborative argument (CSCA) in particular (e.g. Veerman et al. 2002).

A dialogue game model capable of catering for group discussion offers, we suggest, two major advantages in this context. Within collaborative discussions, means of suitably controlling the evolving discussion are required. And given that, as suggested earlier, dialogue game models purport to be models of "fair and reasonable" dialogue, the case for their adoption as the regulatory framework seems clear. In a similar manner, Finkelstein (1992) uses a dialogue game model as the basis for a system for providing automated support for groups collaborating on the development of software specifications. Similarly, the Zeno Argumentation Framework (Gordon et al. 2001) is an Internet-based environment for supporting argumentation, negotiation and group decision making, based on dialogue game principles. The system is conceived as an "intelligent support system for human mediators", which "transforms IBIS from a lifeless method to organise and index information into a playing field for stimulating debate".

A second major benefit of dialogue game models to computer-supported collaboration is that, by providing a computationally tractable model of dialogue, the model makes it possible for a computational agent to participate in the dialogue. This is advantageous in a number of ways. CSCL work is often of a discursive nature and the ability of the computational agent to play a "devil's advocate" role is potentially of educational value (cf. Retalis et al. 1996). This is especially the case, perhaps, in contexts in which the human participants all agree but it is felt educationally advantageous for them to critically explore their shared view. Further, it may be the case in asynchronous computer conferences that propositions posed by one participant evoke little response (Cunningham-Atkins et al. 2004) and that discussion is therefore stymied. A computational agent could potentially provoke discussion in such circumstances. A further advantage of computational participation is that it affords participants the possibility of their own "private" discussion with the agent. This might be used for rehearsal and practice prior to entering the group discussion (perhaps to resolve any "intra-agent conflict" (Amgoud and Maudet 2000)), and/or reflection and analysis after a group discussion. The facility may be particularly useful for people reluctant to enter the group discussion or for people with a social disability such as autism which restricts their participation (cf. Moore et al. 2000). A final advantage of computational participation is that it would enable a number of computers to hold discussions with each other, in a multi-agent system (Amgoud and Maudet 2000) and, given claims concerning the educational benefits of vicarious learning from the dialogue of others (Cox et al. 1999), the resulting transcripts might make educationally valuable study material.

Challenging research issues arise, however, when seeking to apply dialogue games to group discussions. In the event that the group discussion involves two teams being formed, the issue of how team commitment stores (CS) should be updated is complex. The usual arrangement is "de facto commitment" - a participant has to explicitly withdraw from his commitment store those statements of his interlocutor to which he is not prepared to commit (Mackenzie 1979). The position is more complex in a team situation. For different theses can be expressed within a team and this raises the issue of how the other team's CS should be updated. Here, therefore, we propose the notion of "minimal consensus". The minimal consensus is the intersection of the CSs of the players of the team. The idea is that the other team will be *de facto* committed only to this minimal consensus (Maudet and Moore 2001).

A further issue with the team arrangement concerns turn taking. An attractive aspect of the dialogue game framework, particularly from a computational perspective, is the reduction of the turn-taking problem to the following equation: *one move = one turn*. Grasso et al. (2000) express some concern about such an arrangement, and in the context of a set of participants, in particular, the definition may need to be refined. For it may not be realistic to allow only one move for the whole team, nor to oblige one move for each player of the team. A possible solution could be to introduce an explicit turn-taking move, in line with Bunt's "dialogue-control-acts" (Bunt 1994).

In the event of genuine "polylogues", dialogues in which each player wants to achieve a different goal and teams do not therefore form, it is not currently clear what alterations will be needed to the model. This in fact is an example of what we believe to be a fundamentally important research issue, namely the ramifications of computer dialogue research for the field of dialogue games itself. The crucial point, we argue, is that the computer environment can act as a test-bed in which the dialectical theories can be evaluated and refined.

Barrier 4 - Natural language

An obvious concern is the inability of the computer to understand natural language. This issue arises when using dialogue games in a human-computer dialogue. Our debating system mentioned earlier, for example, operates on the basis of a predetermined (albeit expandable) set of propositions, our abstract game operates on a set of predefined abstract arguments, Ravenscroft and Pilkington's (2000) CoLLeGE system adopts a "menu and template scheme" and the Grasso et al. system input and output "consists at the moment of sentences in a first-order language" (Grasso et al. 2000 p. 1097).

It might be argued that even without a general natural language interface, a dialogue game approach still suffices to yield valuable dialogue interactions (Grasso et al. 2000, Ravenscroft and Matheson 2002, Yuan 2004). One can speculate that much of the difficulty in unregulated discussions concerns semantic shifts, and that this is largely ruled out by the propositional logic of the dialogue games. Further, the models provide a valuable service at the propositional logic level, for example by keeping track of commitments and pointing up inconsistencies and consequences of extant positions. And it may be that attempting to work within the confines of propositional logic will turn out to be revealing about what Walton (1989a) sees as the contested ground between semantics and pragmatics. In any event, linking the pragmatic level services of the dialectical model to suitable semantic and syntactic processors should be straightforward, once suitable advances are made in those fields, i.e. computational linguistics.

Summary

This paper has outlined work in applying dialectical theories developed within the field of informal logic to dialogue involving people and computers, i.e. "computational dialectics" (Gordon 1996). We have highlighted four barriers to be addressed if dialogue games are to be successfully applied, and reviewed current and potential approaches, being taken by the authors and others, to overcoming these barriers. Specifically, barrier 1, a lack of flexibility, is being addressed by enriching the dialogue with varying forms of media, by experimenting with amendments to the dialogue game models and by providing for the incorporation of multiple dialogue game types into a single dialogue. Substantive strategies are being developed, for both plays of individual dialogue games and for facilitating dialogues involving multiple games, to address barrier 2, the issue of strategies being needed to operationalise dialogue game models. Barrier 3 concerns the facilitation of group dialogue. For team-based dialogue this is being addressed by amending the dialogue game models to allow for "*de facto* commitment" and explicit turn-taking moves. Means of catering for polylogues remains an open question. The issue of natural language processing (barrier 4) falls outside the remit of dialogue games as such, being rather a matter of computational linguistics, but a variety of practical "ways round" the problem are being adopted in the meantime.

Much remains to be done, then, but the potential pay-off in terms of expanding the human-computer communication and agent communication bandwidth is, we believe, enormous. Further, there is, we contend, great scope for an interesting and fruitful interplay between research within informal logic on the dialogue models per se, and research on their computational utilisation. The hope is that this paper will play some part in moving this interplay forward.

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