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Executive Summary
Negotiation is the process by which two or more parties conduct communications or conferences with the view to resolving differences between them. This process might be formal or mandated as in legal and industrial disputes, semi-formal, as in international disputes, or totally informal as in the case of two prospective partners negotiating as to how they will conduct their married life.

Much work has been performed on developing systems that support human negotiation. These systems range from simple template systems to more sophisticated ones which use reasoning methods from artificial intelligence.

In this paper we provide an in-depth review of current negotiation support tools. The tools range from simple template systems to tools that provide more substantial support. Since negotiation is essentially domain dependent, for the purpose of this paper we have chosen to focus on a specific domain, namely Australian Family Law. Australian Family Law is an appropriate domain because (i) it involves formal negotiation; (ii) there is a sufficient number of accessible cases to evaluate tools; and (iii) it is very relevant in practice, because there are formal negotiation procedures the litigants must undertake before disputes can go to trial. We discuss briefly two negotiation support tools that have been developed in out research group, Split_Up and Family_Negotiator.

Finally we point out at some serious shortcomings of current negotiation support tools. The most important one is their lack of reasoning capabilities that would allow them to provide the user with additional support. We believe that the state of the art can be advanced using artificial intelligence reasoning techniques such as agent programming, argumentation, and belief revision. In the paper we outline our plans for future work in this direction.

1. Motivation, basic assumptions, and overview

Negotiation is the process by which two or more parties conduct communications or conferences with the view to resolving differences between them. This process might be formal or mandated as in legal and industrial disputes, semi-formal, as in international disputes, or totally informal as in the case of two prospective partners negotiating as to how they will conduct their married life.

By its very nature, negotiation is a vague and indeterminate process. Whilst there is numerous psychological research as to how humans negotiate, very few concrete results have emerged. An underlying assumption of our work is that the parties involved in negotiation are rational. It may be argued that this assumption is unrealistic, but we believe that it is reasonable. Here are some reasons to support our view: (i) even if a party acts irrationally, the decision support provided should be rationally founded; (ii) even if a party is irrationally motivated ("I want to hurt the opposite side"), its behaviour might still be modeled as a maximization of a utility function, in which case rational techniques could be used; and (iii) it is good scientific practice to keep a problem feasible by concentrating on some aspects of the problem at hand. Negotiation is a very complex topic even if we blend out its psychological aspects.

The best known negotiation research project is the Harvard Negotiation Project (Fisher and Ury 1981). They originally claimed that the few generally accepted principles of successful negotiation require world knowledge beyond the scope of existing artificial intelligence methods. But the field of intelligent systems has emerged since that opinion was expressed, and there is already a variety of intelligent tools supporting aspects of the negotiation process. We shall review some of them in a later section of this paper.

Our interest in this paper is negotiation *between human parties*. The topic of negotiations between computers has recently attracted considerable interest within the artificial intelligence community, particularly in the framework of multi-agent systems (Kraus, Wilkenfeld and Zlotkin 1995); but this work is outside the scope of this paper.

The organization of the paper is as follows. In *section 2* we survey existing negotiation support tools, mostly using intelligent techniques. In *section 3* we discuss the domain we will be mostly focusing on in this paper, the Australian family law. Negotiation is very domain-dependent, and little work on generic negotiation support tools has been done so far. As we will outline in section 3, the Australian family law is a domain rich in examples and interesting from the applicational perspective.

Section 4 will briefly review two tools we have developed: DEUS and Split_Up. Both provide support for negotiations dealing with the distribution of marital property upon divorce. The ex-partners to the marriage are obliged to attend a negotiation session with a registrar of the Family Court; these sessions are known as Order 24 conferences. Family_Negotiator, presented in *section 5*, uses rule-based and case-based reasoning to provide negotiation support. Finally, *section 6* outlines our current research projects. The main points discussed are: (i) the development of a generic theory of negotiation, so that results from one domain can be used in another domain more easily; (ii) the addition of more sophisticated reasoning capabilities into the tools, so that better decision support can be provided; and (iii) the building of tools that can be useful for a party preparing for negotiation ("what if" analysis, negotiation strategy etc.).

2. Artificial intelligence paradigms for supporting negotiation

General purpose computer tools to support human negotiation are not sophisticated - they generally involve merely completing templates as in NEGOTIATOR PRO and THE ART OF NEGOTIATING (Eidelman 1993) and DEUS (Zeleznikow et al. 1995). Over the past decade research systems have been developed which use artificial intelligence techniques to provide decision support for human negotiators. These have tended to be domain specific, such as in family law (Split-Up (Zeleznikow and Stranieri 1995) and Family_Negotiator (Bellucci and Zeleznikow 1996a, 1996b)), industrial relations (PERSUADER (Sycara 1990) and NEGOPLAN (Matwin et al. 1989)) and international disputes (MEDIATOR (Kolodner and Simpson 1989) and GENIE (Wilkenfeld et al. 1995)).

The earliest negotiation decision support systems used rule based reasoning. For example LDS (Peterson and Waterman 1985) assisted legal experts in settling product liability cases. LDS's knowledge consisted of legislation, case law and informal principles and strategies used by lawyers and claims adjusters in settling cases. SAL (Waterman, Paul and Peterson 1986) helped insurance claims adjusters evaluate claims related to asbestos exposure. These two systems represent the first steps in recognizing the virtue of settlement-oriented decision support systems. Originally NEGOPLAN (Matwin et al. 1989) was a rule based system written in PROLOG which advised upon industrial disputes in the Canadian paper industry. Subsequent work using distributed artificial intelligence techniques has enabled NEGOPLAN to provide more sophisticated generic negotiation advice. GENIE integrates rule based reasoning and multi-attribute analysis.

Case based reasoning was used in both the MEDIATOR and PERSUADER systems. MEDIATOR used case retrieval and adaptation to propose solutions to international disputes whilst PERSUADER integrated case based reasoning and game theory to provide decision support with regard to United States' industrial disputes.

Our preliminary analysis of existing systems (Zeleznikow et al. 1995) reveals many serious limitations in the support they offer for negotiation. The main serious problem is the limited reasoning capabilities of these systems. For example, they do not provide mechanisms for analyzing the argumentation of one side for logical correctness and do not provide strong support to the preparation of counter-arguments to refute arguments of the opposite side. Artificial intelligence

methods that have the potential to enhance the reasoning capabilities of existing negotiation support tools include default reasoning, belief revision, argumentation theories, and multi-agent approaches (for more details see section 6).

3. Australian family law as a negotiation domain

Because the Family Law domain is fraught with conflict resolution processes it provides a fruitful domain for which to build negotiation decision support systems. The prime issues of disagreement in Family Law are the distribution of marital property (and indeed determining what is marital property and the value of such property) and the custody of and access to children. Australian family law is an appropriate domain to model legal negotiation for various reasons:

1. There are formal negotiation procedures the litigants must undertake before disputes can go to trial (Ingleby 1993).
2. Parties to a family law case often need to communicate after the litigation has concluded. Hence, the Family Court of Australia strongly urges parties to negotiate.
3. Family law cases tend to be resolved without formal judgment. In Australia there are approximately 100,000 divorces each year, of which only 5,000 cases are litigated and 1,000 go to judgment. Hence, any model of formal litigation will be directly relevant to about 1% of cases, while a model of negotiation will be relevant to 99% of the cases.

Of the couples who opt for resolution with minimal legal assistance, most have little knowledge of conflict resolution techniques. A computerized implementation can assist by suggesting possible solution paths obtained from previously negotiated cases and to force more focused discussions rather than allowing for discussions where partners blame each other for the breakdown of the marriage.

Thus Australian family law is an area which offers several advantages for studying negotiation. It provides a rich variety of accessible cases; it is significant to the Australian society; it is reasonably formal, and there exists a final instance who will eventually decide any outstanding differences (the courts); and finally, it lies within legal argumentation, an area which has been studied extensively, both with respect to its rules and to intelligent decision support (Zeleznikow and Hunter 1994).

4. DEUS and Split_Up — two negotiation support systems for property distribution

(Zeleznikow and Stranieri 1995) developed a model of family law property negotiation which relies upon building a goal for each of the litigants, with the goals being supported by their beliefs. Goals can only take real number values, because in simplifying the model they assumed that the goal of each party is a monetary figure. Beliefs, which support the goals, are expressed in natural language. In the system which has been implemented using this model, goals are used to indicate the differences between the parties at a given time. The beliefs provided are used to support the goals.

The model calculates the agreement and disagreement between the litigants' beliefs at any given time. The agreement and disagreement are only in relation to the beliefs and hence do not resolve the negotiation. In order to reach a negotiated settlement, it is essential to reduce the difference between the goals to nil. The system only currently calculates the differences between the goals.
Having defined a model, it was implemented in into a system named DEUS. DEUS supports the negotiation process by representing the goals and beliefs of the opposing parties to a property conflict arising from a divorce application. It helps mediators understand what issues are in dispute and the extent of the dispute over these issues.

While this may not seem very intelligent, practitioners such as Linton Drever from Harwood Andrews Solicitors, Geelong Victoria Australia, say determining the amount in dispute is both difficult and critical. Negotiation cannot begin until the extent of conflict has been determined.

DEUS is implemented in an object oriented expert system shell, KnowledgePro. It has excellent hypertext facilities and a user friendly Windows interface which can be used for rapid prototyping.

The Split-Up system offers advice on how property would be distributed if the divorcing couple had their dispute settled by a judgment of the Australian Family Court. Such advice is essential for commencing negotiations. Split-Up integrates the use of rule-based reasoning and neural networks;

for further information on Split-Up, please refer to (Stranieri and Zeleznikow 1995; Zeleznikow and Stranieri 1995).

Let us look at an example. The inputs to the system are the goals of the parties; more precisely, what they think should be included in the common pool (see Figure 1). Split-Up first shows both W and H what they would be expected to be awarded by a court if their relative claims were accepted. Taking superannuation as an example, initially H's goal is set to 0 since he does not believe the wife is entitled to any superannuation. It gives them relevant advice as to what would happen if some, or all of their claims were rejected. They are able to have dialogues with the Split-Up system about hypothetical situations which would support their negotiation. W and H would then have clear ideas about the strengths and weakness of their claims.

	W's goals	H's goals
Custody	yes	yes
Value of house	$400,000	$600,000
Superannuation	$200,000	0
Volvo	$20,000	$20,000
Porsche	$100,000	0
Medical practice	$1,000,000	$500,000
W's salary	$25,000	$25,000
H's salary	$200,000	$80,000

Figure 1: Goals of the litigants

Given the requirements of W and H in the hypothetical example, the Split-Up system provides answers as to the percentages of the distributable assets received by each party; for our concrete example see Figure 2.

	W's %	H's %
Given one accepts W's beliefs	**65**	**35**
Given one accepts H's beliefs	**42**	**58**
Given one accepts H's beliefs but gives custody to W	**60**	**40**

Figure 2: Percentage split calculated by Split_Up

It should be noted that it is coincidental that 60% is given to W, since the hypothetical was designed well before it was used in Split-Up. Thus, we can see that we have determined that if the husband were to grant custody of the children to the wife, he should also give her 60% of the distributable assets - which is exactly what the wife requires.

5. Family_Negotiator

5.1 Overview

Family_Negotiator deals with three distinct areas of negotiation in Australian Family Law:

1. Determining child custody;
2. Determining contents of common pool;
3. Determining the percentage split of the common pool.

Requirements of the negotiation process include stance revision capabilities; and hence the ability to generate alternate compromising solutions (Sycara 1990). Some aspects of a family law settlement make extensive use of well-known heuristics. Hence, a hybrid rule-based and case-based system, employing Principled Negotiation as its negotiation strategy (see section 3) has been implemented to model the domain of family law disputes.

In Family_Negotiator cases are stored in the case-base as actual instances of relevant experience, to be referenced by the case-based reasoner. Rules are stored and referenced within the relevant subsections of the program that support rule-based reasoning. The system is thus a hybrid rule-based and case-based reasoner.

To describe the paradigms used by the system, a two level approach is required. At the top level, Family_Negotiator is a hybrid rule-based/case-based reasoner, since its total functionality is determined by either rule based, case based or integrated rule-based and case-based inferencing. These inferences refer directly to the reasoning mechanisms employed in each module, which make up a second level of reasoning. For example, the component of the system that negotiates child custody is totally case-based, whereas determination of the percentage split in property settlements makes use of both case-based and rule-based reasoning.

5.2 The case-bases

Three frames for the case-base analysis have been implemented. Each case-base holds cases of one frame type. The custody case-base contains all arguments pertaining to child custody issues. The basic case-base holds primary knowledge of the case, while percentage split information is stored in the percentage case-base.

The *basic_frame* provides general information about the case, including the number of years of marriage, whether they have children and a list of issues with which the case needs to deal. This frame is used in negotiating an appropriate ordering of issues, by retrieving a plan for the negotiation process. The other two frames, the custody_frame and the percentage_frame, represent the actual arguments presented and their resolutions in the child custody and percentage split issues respectively.

The *custody_frame* stores attributes relevant to specific custody cases. Such attributes include

- the case number and case argument number
- the number of children in the marriage
- the wish of each child (if it was older than 14)
- the husband stance and the wife stance (with values such as "wants full custody")
- husband reasoning and wife reasoning explaining their stance (for example, "To keep the children together" or "I am able to be home more often")
- the solution, with values such as "custody to wife"
- an indication whether the solution was accepted, that means, whether the negotiation was successful.

The *percentage_frame* stores similar information, such as the Case_no and Case_arg, and the Husband_stance, Wife_stance and supporting reasoning slots. The percentage split of the pool is recorded as is the solution. Family_Negotiator represents negotiation as a gradual series of argumentative steps, that collectively approach the common goal of mutual agreement in divorce disputes.

5.3 Case-based reasoning

Once all the cases have been read into memory, the program tries to find the closest matching case to the current case presented. The retrieval algorithm applied in the system is the "Nearest Neighbour" algorithm, which calculates a case dependent weight by measuring the degree of similarity between the current case and cases in the case-base, through a method of pattern matching on single attributes. Since the same case-base can be referenced for use in more than one issue, a set of importance values are input into the case-inferencer, values of which are representative of domain expertise.

The use of neural networks as an alternative retrieval algorithm was rejected. Rule induction proceeds to generalize cases into rules and does not capture the detail and depth the domain requires. The Nearest Neighbour algorithm worked well, since it complements the principles of hybrid reasoning, and in particular that of case-based reasoning.

5.4 Determining the common pool using rule-based reasoning

Rule-based reasoning is employed in the module dealing with determining of the contents of the final common pool. The contents have been classified into several classes, including real estate, chattels, business assets, choices in action and vested interests. The rules implemented in the system represent the common heuristics applicable to the determination of the common pool.

The overall heuristic is to include in the common pool all property acquired during the marriage, as well as any future acquirement of finances that is currently foreseeable. The rule base, containing nine if-then-else constructs operates using the forward chaining algorithm. According to the responses entered by the users, the corresponding rules are fired, a sample of which following.

1. IF property was not acquired during the marriage
   THEN do not include in the common pool.
2. IF property was a gift or inheritance given to one party only
   THEN do not include in the common pool.
   ELSE include in the common pool.
3. IF property is owned by both parties OR property is owned by one party only
   THEN include in the common pool.

Rules 1, 2 and 3 ask the users for information regarding property. The rule-base is designed to ensure that if a rule with a consequent of non inclusion in the common pool is fired, then the system assumes agreement. If the rule-based reasoning mechanism has reached the end of traversing all rules, the argument has been settled by inclusion of the item in the common pool.

The third rule is in fact quite simplistic. A more detailed analysis of marital property division can be found in (Wilkenfeld et al. 1995). Through numerous interviews with domain experts and an analysis of past cases (using neural networks) we have noted that where applicable, the parent who has custody of dependent children) has greater future needs than the other parent in that the custodial parent must spend more time caring for children (which might otherwise be spent earning income). There are of course other factors involved in determining future need: such as age, health, education, employment history. However rule-based systems are limited in their modeling power. Thus the current third rule in Family_Negotiator described above assumes the custodial parent is the wife (which is generally the case) and future needs are determined solely by income.

5.5 Recommended splitting

Once the contents of the common pool have been determined, and hence a figure representative of total value of the common pool is obtained, a determination of the percentage split between the couple can be decided. Family_Negotiator does not take into consideration the possibility of splitting property item by item, but bases the split on the collective common pool. The latter approach has been employed for ease of modeling, and to satisfy the understanding that the greater the value of the common pool, the greater the amount (in dollars or otherwise) to be distributed to each party, regardless of which items are given to whom.

Percentage splits of the common pool value are controlled by hybrid rule-based and case-based reasoning, in which the rules, representing heuristics and 'norms', are fired foremost, and if solutions obtained from the rule-base are refused, then the case-base will aim to retrieve a more successful suggestion.

At first several heuristics are fired to either attain settlement immediately, or try to persuade the parties to revise their claims. Since the 50/50 percent norm is often employed in property settlement cases, this is the first rule to be fired. If the couple accept this recommendation, then negotiation has been successful, and the solution is recorded with the current case. If the couple reject the above suggestion, the system will attempt to fire the following rules:

IF children are involved AND custody of children has been decided,
THEN the party with custody has rights to a greater percentage
IF income of husband is greater than income of wife,
THEN wife is entitled to a greater percentage
ELSE husband is entitled to a greater percentage.

The latter rule is used because the party with a lower income has greater future needs and is thus, by the Family Law Act (1975), entitled to a greater percentage of the common pool. The above rules aim to revise the percentages claimed. If such a revision takes place, and their summation adds to 100 percent, then a settlement is achieved, and the solution is recorded as a success with the comment "revision due to rule no. x" . If a problem still exists, the case-based reasoner is invoked. An argument is only recorded as 'failed' if the total process through the rule-base and case-base has proved unsuccessful in achieving agreement. If a new argument is commenced, that is the stances of parties have changed, the solution slot of the previous contains the string "next_arg_2" to suggest the case has not been solved, but revisions have occurred, stored in argument 2 under the present case-no.

The order in which the heuristics are presented is rdpresentative of the firing order in the module, hence providing for the minimum number questions asked of users. For example, rule 2 will be fired if the system searches through the basic case-base and finds children involved. If the issue of child custody has been resolved within the same case, the rule fires. Consequently, if one of rules 3 or 4 is fired, the parties' individual income declarations will be requested, with suggestions leading to the revision of stances.

5.6 The negotiation

Family_Negotiator requires the user to enter as input those issues which are yet to be resolved. If the parties do not agree to the ordering of these issues, the case-base is consulted and a relevant adapted plan is retrieved and presented to the parties. This process ensures the parties have complete control over the issues and when these issues are to be negotiated.

Once a plan for negotiation has been agreed upon, negotiations can commence. Each issue is dealt with separately by different modules. Information passing from the user interface to negotiation modules is the number calling each negotiation procedure. After each issue has either successfully negotiated or an impasse arises, the next issue commences. The cycle comes to an end when all issues have been dealt with by Family_Negotiator. When an issue is terminated by either party, a failure is recorded in the comments slot of the relevant case-base, enabling retrieval for later cases. The system refers to three case-bases, each one holding cases of one frame type. Hence, custody case-base contains all arguments pertaining to child custody issues, basic case-base holds all knowledge stored in the basic frames, and arguments pertaining to percentage split issues are stored in the percentage_frame, referenced through the percentage case-base.

6. Current and future work

In this paper we reviewed methods of artificial intelligence that have been used to aid negotiation between humans. Then we turned our attention to Australian family law, a rich and interesting domain for which we have expertise. We discussed some of its characteristics, and described three negotiation support tools that have been completed and work in this domain.

Even though these tools are successful, and there are plans to commercialize at least one of them, there is still a lot of work to be done in the area of intelligent decision support for negotiations. One point regards the domain dependence of the work so far. As we already stated, negotiation is very domain-specific. Therefore it is currently very difficult to carry over ideas or tools from one domain to another. It would be a major leap forward if we could develop a generic theory of negotiation. Such theories for *legal* negotiation have been proposed in the literature (Gordon 1994; Prakken 1993; Stranieri and Zeleznikow 1995), and can be a first step towards more generic theories of negotiation. Other specific techniques that we intend to study for their use in intelligent negotiation support tools include the following.

(a) Default Reasoning, Nonmonotonic Reasoning

It would be an important improvement would be if we could increase the reasoning capabilities of existing systems. One possibility is to use forms of default reasoning (Antoniou 1997; Reiter 1980), a kind of nonmonotonic reasoning, to formalize argumentation within a negotiation process. This form of reasoning has an advantage over more classical approaches, in that it regards arguments and statements to be defeasible in nature, open to disputation (for example from the opposite side in the negotiation. A starting theory is provided by Brewka's reconstruction of Rescher's theory of formal disputation (Brewka 1994; Rescher 1977).

(b) Reasoning about Beliefs, Desires and Intentions
Another possible approach is to use reasoning on beliefs, desires, and intentions. Work on such BDI-architectures involves researchers from philosophy (Bratman 1987) and artificial intelligence (Rao and Georgeff 1991). It will be interesting to study whether and how this framework can be used to model negotiation. The main advantage of this approach is that it offers a rich language to express beliefs, intentions and desires of agents, as they work together towards a solution. Certainly this rich expressiveness is quite suitable to negotiation processes, but we will have to check whether this advantage translates to practical benefits.

(c) Belief Revision
In a negotiation, every side has its own beliefs and goals that it wants to achieve. If we could provide mechanisms for reasoning with beliefs and goals of each side, it would greatly enhance the functionality of negotiation tools. Even more so since these goals are not necessarily static, but instead they change dynamically as negotiation proceeds. Belief revision (Gardenfors 1992) offers formal methods for reasoning about change, so it could be the right method to look at for such problems. The current frameworks allow one to assign numerical values to sentences (representing arguments, beliefs or goals), but use them in a qualitative way. We intend to study ways of making use of these values in a quantitative way, which is particularly important in disputations involving financial matters.

(d) Theories of Argumentation
Argumentation is a multi-disciplinary research topic, with input from formal and informal logic, philosophy, linguistics, artificial intelligence, legal reasoning etc. By its nature, argumentation theory may turn out to be more fruitful for studying the negotiation process than, say, default reasoning, because it stresses the analysis and evaluation of argumentation in a dialogical context (Henkemans 1992). The study of arguments, counter-arguments, attack and defeat of arguments lies at the heart of this theory.

A particular approach of argumentation is *dialogue logic* (Henkemans 1992; Walton and Krabbe 1995). Within its framework there are specific rules that should be followed in order to produce a meaningful disputation. Elements of this framework include defending a statement, challenging a statement, the withdrawal of statements etc. Interestingly dialogue logic can be viewed as a kind of *joint activity system* (Girle 1996).

The tools we described in this paper assume that the negotiation parties essentially sit together, disclose their beliefs and goals, and work together towards an acceptable solution. The tools offer, of course, significant help, but there is an alternative use that is conceivable. The tools could be used by one party in its *preparation for the negotiation*. In the most trivial case, the party might just use any of the tools we described, inputting what it assumes that the opposite side would input. Of course, the party could run manually several hypothetical trials to see what possible outcomes might be.

Obviously it would be helpful if this process could be automated, in other words, if a system would offer a "what if" analysis. In terms of reasoning, this is known as *hypothetical reasoning*, and several possible approaches have been proposed, some of the most notable based on default reasoning and belief revision which were mentioned before. Hypothetical reasoning would allow a party to prepare for negotiation, having prepared possible reactions to some critical situations that might arise. Not being taken by surprise is an important factor for reaching a favourable negotiated settlement. We could also imagine tools which would ask the user to input their goals in a specific ranking, indicating which they would be prepared to give up. This information could further enhance the benefits from hypothetical reasoning, if one is prepared to give up something for a more important benefit.

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