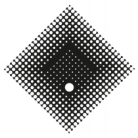

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Incorporating Fairness into Development of an Integrated Multi-agent Online Dispute Resolution Environment

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Abstract The paper describes the development of an integrated multi-agent online dispute resolution environment called IMODRE that was designed to assist parties involved in Australian family law disputes achieve legally fairer negotiated outcomes. The system extends our previous work in developing negotiation support systems Family_Winner and AssetDivider. In this environment one agent uses a Bayesian Belief Network expertly modeled with knowledge of the Australian Family Law domain to advise disputants of their Best Alternatives to Negotiated Agreements. Another agent incorporates the percentage split of marital property into an integrative bargaining process and applies heuristics and game theory to equitably distribute marital property assets and facilitate further trade-offs. We use this system to add greater fairness to Family property law negotiations.

Keywords BATNAs · Bayesian belief networks · Integrative negotiation · Multi-agent systems · Negotiation supports systems · Online dispute resolution

1 Introduction

One of the major concerns raised by people using Negotiation Support Systems (NSS) is about the fairness of the process. Individuals undertake negotiation to derive better outcomes than could be obtained from conflict and litigation. Thus, they often engage

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in interest based negotiation. But interest based negotiation focuses upon the interests of disputants rather than upon objective measures of fairness or justice. For example in Australian family law, differences in power between men and women may lead to negotiated results that favour men. Bargaining imbalances can thus produce unfair results unless mediators or NSS overcome them. It is thus vital to incorporate measures to address fairness in the development of NSS.

The research aims to assist disputants achieve legally fairer negotiated outcomes through development of an integrated online dispute resolution (ODR) environment (IMODRE) that incorporates their best alternatives to negotiated agreements (BATNAs) into an integrative bargaining process. The notion of a BATNA was introduced by Fisher and Ury (1981) as an integral factor in their development of principled negotiation. Principled negotiation promotes deciding issues on their merits rather than through a haggling process focused on what each side says it will and will not do.

The reason you negotiate with someone is to produce better results than would otherwise occur. If you are unaware of what results you could obtain if the negotiations are unsuccessful (your BATNA), you run the risk of entering into an agreement that you would be better off rejecting; or rejecting an agreement you would be better off entering into. Including a BATNA in the bargaining process provides a starting point for negotiations and allows disputants to trade-off assets within the parameters of likely litigated outcomes.

IMODRE provides negotiation advice in the domain of Australian Family Law disputes, and was developed on a multi-agent platform with individual agents deployed to carry out specific negotiation tasks. One agent uses a Bayesian belief network and an adaptation of Toulmin argument structures[1] (Toulmin 1958) to recommend a percentage property split[2]. This advice represents a disputants' BATNA. Another agent combines this percentage split with heuristics and game theory to facilitate integrative bargaining between parties.

The research is supported by industry partners Relationships Australia (Queensland branch)[3] and Victoria Body Corporate Services[4], both of whom believe there are significant benefits to be gained for their clients by investing in innovative new approaches to dispute management.

The paper commences with a discussion of various negotiation strategies including the concepts of bargaining in the show of the law, the notion of a BATNA, and integrative and distributive type negotiations. We also explain which strategies have

[1] The adaptation of Toulmin (1958) we use views all arguments, regardless of the domain, as having a structure which consists of four basic invariants: claim, data, warrant and backing. Every argument makes an assertion. The assertion of an argument stands as the claim of the argument. A mechanism is required to act as a justification for the claim, given the data. This justification is known as the warrant. The backing supports the warrant and in a legal argument is typically a reference to a statute or precedent case.

[2] One of the steps judges of the Family Court of Australia follow in order to determine the distribution of marital property is to arrive at a determination of the percentage of property to be awarded to each partner (Zeleznikow 2004).

[3] http://www.relationships.com.au/who-we-are/state-and-territory-organisations/qld. Last accessed 2 January 2010.

[4] http://www.vbcs.com.au/. Last accessed 2 January 2010.

been applied our system. The paper then provides an overview of NSS and describes examples of their current use and potential advantages. The next section discusses how intelligent agents are increasingly being used to provide negotiation support. Our previous work in developing the NSS AssetDivider is then demonstrated to provide a background perspective of our research.

Section 5 presents our multi-agent NSS architecture with a step by step example used to demonstrate the typical system processing and individual agent functionality. The paper concludes with a discussion of our industry partners' involvement in the project and describes how we are evaluating the current system. We also present the research design for a more comprehensive evaluation of our integrated ODR environment.

2 Negotiation Strategies

This section provides an overview of various negotiation strategies and explains the rationale for choosing the strategies that are deployed in the IMODRE system.

2.1 Bargaining in the Shadow of the Law and the Notion of a BATNA

Traditional negotiation support systems (NSS) have focused upon providing users with decision support on how they might best achieve their goals (Raiffa 1982). A fundamental issue arises whenever anyone builds a NSS for use in legal domains: is the system being developed concerned with supporting mediation or providing justice? When issues of justice are not reflected in the outcome of the mediation process, bargaining theory has its limitations. Because most legal dispute resolution occurs outside the court-room, there are fewer opportunities to ensure fair decision-making. In support of this argument, Galanter (2004) claims:

> In the federal courts, the percentage of civil cases reaching trial has fallen from 11% in 1962 to 1.8% in 2002. In spite of a five-fold increase in case terminations, the absolute number of civil trials was 20% lower in 2002 than it was 40 years earlier.

In writing about the Vanishing American Trial, Galanter argues that whilst litigation in the United States is increasing, the number of trials decided by US judges has declined drastically. This is because litigants are using alternative forms of Dispute Resolution.

Negotiations in law are often conducted in the shadow of the Law, i.e. bargaining in legal domains mimics the probable outcome of litigation. Mnookin and Kornhauser (1979) introduced the bargaining in the shadow of the trial concept. By examining the case of divorce law, they contended that the legal rights of each party could be understood as bargaining chips that can affect settlement outcomes.

A similar view of negotiation is expressed by Bibas (2004) who states that:

> the conventional wisdom is that litigants bargain towards settlement in the shadow of expected trial outcomes. In this model, rational parties forecast the

expected trial outcome and strike bargains that leave both sides better off by splitting the saved costs of trial. This shadow of trial model now dominates the literature on civil settlements.

A crucial component to bargaining in the shadow of the law is the Notion of a BATNA. Fisher and Ury (1981) introduced the notion of a BATNA concept as a tool for negotiators to cope with power imbalances. As stated above, they claim that, if negotiators do take account of their options outside a negotiation, they are better protected against agreements that should be rejected. It also helps them to reach agreements that better satisfy their interests. In order to assess whether an offer should be rejected, a party in a dispute has to establish what can be accomplished in alternative procedures to the one currently being conducted. Once the alternatives are known, these can be compared to what one expects to win by accepting an offer in the current procedure.

For example, when a person wishes to buy a used car, they will usually refer to a commonly accepted set of approximate automotive prices. Using this initial figure and considering other variables such as new components, the distance traveled by the car and its current condition, the buyer then decides the value they wish to place on a car. If the seller is not willing to sell the car at this price, then they can argue the merits of their valuation in an attempt to persuade the seller to accept their BATNA.

Alexander (1997) argues that because women tend to be more reluctant than men to continue conflict, if their major goal is to be the primary care giver for their children, they may reach a negotiated settlement, which whilst acceptable to them is patently unjust. Bargaining imbalances can thus produce *unfair results* unless mediators or NSS overcome them. Take for example a marriage in Australia where the couple have been married for 15 years and have three children, one of whom has special needs. Suppose the husband works full-time, whilst the wife is not employed outside the house and is a full-time carer for the husband and children. Suppose they own a house valued at $400,000 with a mortgage of $250,000. Further, the husband earns $45,000 per annum. Given that this is both a low income and low asset marriage (the common pool is let us say $180,000) the wife might be expected to receive 70% of the common pool in a family court settlement. This 70% split represents the wife's BATNA.

As an important starting point in a negotiation, BATNAs can be used to form a basis from which fair agreements can be obtained, thus, incorporating a BANTA into the negotiation process offers a degree of safety against power imbalances that may occur with these types of negotiations.

2.2 Integrative and Distributive Negotiation

Ponte and Cavenagh (2004) define negotiation as a process of refining and agreeing to the issues requiring resolution, establishing a range of compromise options from which to choose and selecting the appropriate option for settlement. Essentially negotiation requires a balancing of one's own needs with a view toward arriving at an agreement that satisfies both sets of requirements.

Walton and Mckersie (1965) propose that negotiation processes can be classified as distributive or integrative. In distributive approaches, the problems are seen as "zero

sum" and resources are imagined as fixed: divide the pie. In integrative approaches, problems are seen as having more potential solutions than are immediately obvious and the goal is to expand the pie before dividing it. Parties attempt to accommodate as many interests of each of the parties as possible, leading to the so called win–win or all gain approach. As Kersten (2001) notes, although Walton and McKersie did not suggest one type of negotiation being superior to the other, over the years, it has become conventional wisdom that the integrative type allows for better compromises, win–win solutions, value creation and expanding the pie. Fisher and Ury (1981) and Lax and Sebenius (1986) discuss these issues in detail.

Most negotiation outside the legal domain focuses upon interest-based negotiation. Expanding on the notion of integrative or interest-based negotiation, principled negotiation promotes deciding issues on their merits rather than through a haggling process focused on what each side says it will and will not do (Fisher and Ury 1981). Amongst the features of principled negotiation are: separating the people from the problem; focusing upon interests rather than positions; insisting upon objective criteria and knowing your BATNA.

In Family_Winner (Bellucci and Zeleznikow 2006), we applied an integrative bargaining model to develop our NSS. Initially disputants were required to indicate explicitly how much they value each of the different issues in dispute by distributing 100 points across the range of issues. If as is generally the case, the disputants do not have directly opposing goals, it is likely that each disputant will receive more than 50 points. This is an improvement on any strategy that is based on the zero-sum philosophy, where each party wins what the other loses, and thus, leads to the so-called win–win or all gain approach.

In more recent versions of our software linguistic variables are used. It is more natural for disputants to express how they value items in a dispute in terms of language, rather than numbers. The language can of course be translated into numbers, as explained by Zeleznikow and Bellucci (2006).

3 Negotiation Support Systems

This section provides on overview of NSSs, including the various types that are available, specific applications in use today, and potential advantages of using such systems.

3.1 Background to Negotiation Support Systems

Many NSSs such as Adjusted Winner (Brams and Taylor 1996), Smartsettle (Thiessen and McMahon 2000) and Family_Winner use bargaining and game theory to provide win–win solutions to participants in disputes. Adjusted Winner and SmartSettle—can be used to provide negotiation advice whereas Split-Up (Stranieri et al. 1999) and AssetDivider (Bellucci 2008) focus upon decision support for negotiation.

Adjusted Winner is a two party point allocation procedure that distributes items or issues to people on the premise of whoever values the item or issue more. The two disputants are required to explicitly indicate how much they value each of the different issues by distributing 100 points across the range of issues in dispute. In this paradigm,

it is assumed there are k discrete issues in dispute, each of which is assumed divisible. The Adjusted Winner paradigm is a fair and equitable procedure because at the end of allocation, each party will have accrued the same number of points.

SmartSettle is an interactive computer program developed to assist those involved in negotiating agreements among parties having conflicting objectives. The system can be used during the negotiation process by opposing parties or by a professional mediator. On the basis of information provided to the program, in confidence, by each party, the NSS can help all parties identify feasible alternatives, if any exist, that should be preferred to each party's proposal. If such alternatives do not exist, the program can help parties develop counter proposals.

SPLIT-UP is a hybrid rule based/ neural network system that uses textbooks, heuristics, expert advice and cases to model that part of the Family Law Act 1975 (Australia) which deals with property division. Explanation is provided through the use of Toulmin argument structures. Though Split-Up is a *decision* support system rather than a *negotiation* support system, the tool does provide disputants with their respective BATNAs and hence provides an important starting point for negotiations (Lodder and Zeleznikow 2010).

Family_Winner asked the disputants to list the items in dispute and to attach importance values to indicate how significant it is that the disputants be awarded each of the items. The system uses this information to form trade-off rules. The trade-off rules are then used to allocate issues according to a "logrolling" strategy[5].

AssetDivider, which is described in detail in Sect. 4, is a system developed to meet the needs of family dispute resolution practitioners (FDRPs) at Relationships Australia (Queensland). The program generalises Family_Winner by including financial values of property and allowing FDRPs to move the negotiation (so as to meet the *paramount interests of the children)* in favour of one party to the negotiation.

In considering the principles and theory underlying their integrated online dispute resolution (ODR) environment, Lodder and Zeleznikow (2005) first evaluated the order in which online disputes are best resolved. The system proposed conforms to the following sequencing, which produces the most effective ODR environment:

(1) First, the negotiation support tool should provide feedback on the likely outcome(s) of the dispute if the negotiation were to fail—i.e., the BATNA.
(2) Second, the tool should attempt to resolve any existing conflicts using argumentation or dialogue techniques.
(3) Third, for those issues not resolved in step two, the tool should employ decision analysis techniques and compensation/trade-off strategies in order to facilitate resolution of the dispute.

Finally, if the result from step three is not acceptable to the parties, the tool should allow the parties to return to step two and repeat the process recursively until either the dispute is resolved or a stalemate occurs. A stalemate occurs when no progress is made when moving from step 2 to step 3 or vice versa. Even if a stalemate occurs,

[5] Logrolling is a process in which participants look collectively at multiple issues to find issues that one party considers more important than does the opposing party. Logrolling is successful if the parties concede issues to which they give low importance values. See Pruitt (1981).

suitable forms of ADR (such as blind bidding or arbitration) can be used on a smaller set of issues.

In the domain of Australian Family Law, Split-Up provides advice about BATNAs, whilst Family_Winner and AssetDivider employ decision analysis techniques and compensation/trade-off strategies to facilitate resolution of the dispute. Conceivably, an Online Family Dispute Resolution Service could consider the provision of advice not only about outcomes and BATNAs, but also about processes and how disputants should act '*fairly*' and '*reasonably*' during the mediation.

3.2 The Benefits of Online Negotiation Support

Katsh and Rifkin (2001) state that compared to litigation, alternative dispute resolution (ADR) has the advantages of (a) Lower cost; (b) Greater speed; (c) More flexibility in outcomes; (d) Less adversarial; (f) More informal; (g) Solution rather than blame-oriented; and (h) Private.

Online dispute resolution is a branch of dispute resolution which uses technology to facilitate the resolution of disputes between parties. Primarily, ODR involves negotiation, mediation or arbitration, or a combination of all three. In this respect, ODR is conceivably, analogous to ADR. However, ODR can also augment these traditional means of resolving disputes by applying innovative techniques and online technologies to the process.

Zeleznikow and Bellucci (2003) suggest that in terms of family mediation, ODR has the following additional benefits over ADR:

- Disputants do not have to meet face-to-face: an important factor if there has been a history of violence; and
- Family dispute resolution (FDR) can occur at any time, with participants located in different countries.

The use of Information Technology can further promote many of the benefits of ADR.

- By receiving advice online, and in particular receiving such advice from decision support systems (DSS), costs incurred in the dispute will be reduced because the disputants will have a lower reliance on support from lawyers and mediators.
- Because the advice will be available online, or at least through the use of computer systems, such advice will be timely and mostly in real time to inform the agreement.
- The backlog in disputants seeing lawyers or FDRPs will be less critical than currently - anecdotal evidence shows that time taken to hear a dispute is often a factor in successful resolution of a dispute. The sooner disputants are able to have their views heard; the more likely is the prospect of a successful resolution.
- One major advantage of using NSSs for advice is the ability for disputants and FDRPs to conduct hypothetical sessions with the systems.
- Rather than mandate solutions, NSSs such as Family Winner (Bellucci and Zeleznikow 2006) can offer disputants advice—which they are free to reject. Further, if users of the system are unhappy with the advice given by the system,

they can alter their inputs. This approach forces the disputants to re-examine their priorities.
- Because of their ability to efficiently search through a wide variety of solutions and meet disputants' needs, NSSs can provide more flexibility in providing a useful range of outcomes.

Conley Tyler and McPherson (2006) propose that ODR potentially offers advantages over face-to-face primary family dispute resolution in the following circumstances:

- ODR makes it possible to provide family law dispute resolution services to parties who are geographically remote. In the past, the process of separation and divorce involved written correspondence and expensive litigation, increasing the cost in terms of time and travel and accommodation. Given that the settlement of a divorce comes out of the one pool of assets, any methodology in the separation process that reduces costs clearly benefits the agreement negotiations
- ODR offers the opportunity for managing the contact and communication in a less threatening situation where domestic violence, perceived power imbalance or abuse is a factor in the relationship
- Use of the on-line methods also allows for the prompt and virtually immediate delivery of progress and agreements made during the FDR and of settlement proposals
- ODR can be used in combination with face-to-face dispute resolution when it is used to clarify stories and issues before a meeting and to facilitate post-FDR session actions, negotiations and drafting the terms of settlement (Boulle 2005).

To assist the on-line media to manage negotiations and resolve disputes among couples, as mentioned above, a range of negotiation support systems are available to augment the decision making processes. DSS are used in a range of situations including medicine, military and aeronautical contexts. In the FDR context, similar technologies have been specifically developed to meet requirements. NSS offer further enhancements to conceivably increase effectiveness, fairness and satisfaction with the FDR process.

3.3 Agents and Negotiation

There has been much research on intelligent agents and automated negotiation. See for example Kraus (2001). She claims:

> Negotiation has been a subject of central interest in multi-agent systems, as it has been in economics and political science. The word has been used in a variety of ways, though in general it refers to communication processes that further coordination and cooperation. Negotiations can be used to resolve conflicts in a wide variety of multi-agent domains (Jennings et al. 2000). Examples of such applications include conflicts over the usage of joint resources or task assignments, conflicts concerning document allocation in multi-server environments and conflicts between a buyer and a seller in electronic commerce.

Kraus et al. (2008) state:

> Our goal is the development of automated agents that can negotiate efficiently with people in crises. Such agents may be used, for example, in electronic commerce and for training negotiators. We focus on bilateral negotiations in simulated crises characterized by time constraints, deadlines, full information, and the possibility of opting out.
>
> The automated agent can play the role of either side in such negotiations. The model used on which the automated agent is based is a formal analysis of a scenario using game-theoretic methods and heuristics for bargaining. The formal analysis applies a definition of a crisis that models various aspects of such situations. In particular, a crisis is a conflict between two agents that threatens core values, where time is short, and that requires urgent negotiation to reach an agreement. The crisis can end with the negotiators signing an agreement or with one of the sides opting out of the negotiations.

Today, artificial intelligence (AI) can be seen as the study and design of intelligent agents, where an intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success (Russell and Norvig 2003). Among the traits that we believe make an agent based approach a suitable platform for developing our NSS are reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects.

Our NSS can be implemented in its present form with conventional Web based programming techniques and simple remote procedure calls using, for instance, the SOAP protocol[6]. A multi-agent platform is more suitable for our needs, however, because it allows us to implement a distributed architecture with independent services offering a degree of autonomy, including AI techniques such as Bayesian reasoning, game theory, and linguistic analysis of text. Intelligent agents are a favoured method of implementing these techniques within the AI community.

The multi-agent platform allows part of the negotiation process to be automated. For instance, we are developing a mediator agent capable of guiding disputants through the mediation process with features such as linguistic analysis to identify dispute agenda items, automatic text summary to clarify parties opening positions, and assistance for mediators with readily available questions and responses at appropriate stages of the mediation.

4 Family_Winner and AssetDivider

This section presents our previous work in developing the NSS Family_Winner and AssetDivider.

4.1 Research Background

The research builds on our previous work in developing the NSS Family_Winner and AssetDivider. Family_Winner (Bellucci and Zeleznikow 2006) is a system that

[6] http://www.w3.org/TR/2000/NOTE-SOAP-20000508/. Last accessed 11 January 2010.

allocates items to one of two parties in the dispute. Family_Winner's method of decision support involves a complex number of techniques, including the incorporation of an Issue Decomposition Hierarchy, a Compensation and Trade-off strategy, and an Allocation strategy. The trade-offs pertaining to a disputant are graphically displayed through a series of trade-off maps.

Family_Winner provided decision support for mediators. Whilst it had an underlying principle of meeting the disputants' needs to similar degrees, it realized that most disputants have fuzzy views of their desires, and these desires regularly change. Hence an exact equality of points was not required. Family_Winner was initially developed with expert legal advice from Victoria Legal Aid, and more recently with the Queensland Branch of Relationships Australia. When we evaluated Family_Winner (Zeleznikow and Bellucci 2003), Victorian Legal aid noted that the system focused upon meeting the interests of the parents (as would Adjusted Winner, Smartsettle and indeed most NSSs). But in Australian Family law, the notion of fairness or justice is concerned with meeting *the paramount interests of the children* and not the interests of the parents.

An updated version of Family_Winner called AssetDivider was later developed at the request of the Queensland Branch of Relationships Australia (RAQ), who wished to use our software to support family dispute resolution practitioners and disputants to arrive at legally fair solutions. As discussed in Sect. 6, RAQ had become aware of the existence of Family_Winner through the ABC Science Show the New Inventors. The Family_Winner system works on the principle that both parties in a dispute should have their needs equally met (as is traditionally the case in integrative bargaining). Because RAQ focuses upon the paramount interests of the children and not the interests of the parents[7], they wanted us to construct a system where RAQ FDRPs could propose a percentage split to reflect the percentage of the common pool of assets each party should receive in the final settlement. The AssetDivider software would then provide negotiation decision support based on this advice. Thus a significant additional feature of AssetDivider over Family_Winner is the consideration of monetary values and the required percentage split for the pool items in dispute.

4.2 AssetDivider User input

Asset_Divider takes a list of issues (usually items for distribution between two parties) and allocates them based on a rating given by the parties in dispute. Two sets of ratings are provided, one for each party in dispute. This rating (initially a numerical value between 0 and 100, but now a linguistic variable) does not represent the monetary value of the item, instead it symbolises how important the item is to the party. Initially this information was obtained by asking disputants to provide numbers for their desires. But whilst such a task might be difficult, especially when involved in a

[7] Unlike the case in most US jurisdictions (where Family Law is a state matter), under Australian law, parents have no rights, only obligations. For example, in a dispute over the welfare of the children, biological parents have no extra rights or influence compared to other careers.

dispute, as explained in Sect. 5, asking disputants to order their preferences is indeed natural. We assume a party wants to keep an item they feel is important to them.

AssetDivider also accepts the current monetary value of each item in dispute. We assume this dollar value has been negotiated (if necessary) before AssetDivider is used. Hence, only one dollar value is entered per item. The proposed percentage split is also entered. This figure has to be derived from the mediator's knowledge in past cases or from computer systems such as SplitUp (Stranieri et al. 1999), which can provide a percentage split given certain characteristics and features of divorce cases.

4.3 Allocation Strategy

The order by which issues are allocated is of paramount importance in a negotiation. Professional mediators have indicated issues attracting little disputation should be presented foremost for allocation, so as to help foster a positive environment in which to negotiate. By summing the ratings of issues to 100, the level of discourse surrounding an issue can be measured by calculating the numerical distance between the ratings of an issue assigned by each of the parties (Zeleznikow et al. 2007). For example, if two parties assign the same high rating to an item, then it is expected the level of disputation surrounding the issue to be substantial (because both parties want the item), whereas large differences between the ratings of parties indicate the issue will be resolved much more quickly. Both Family_Winner and AssetDivider use this strategy in deciding the order by which items are presented for allocation.

AssetDivider's allocation strategy works by provisionally allocating an item to the party whose rating is the highest. It then checks the dollar value of items it has been allocated previously (that is, their current list of items), the dollar value of the item presently allocated and the dollar amount permitted under the percentage split given by mediators. If by allocating the item in question the party exceeds its permitted amount, the item is removed from its allocation list and placed back into negotiation. In this case, the item has not been allocated to a party. If the dollar value of the item was within the limits of the amount permitted under the percentage split rule, then the allocation proceeds. Once an allocation has occurred the 'losing party' is compensated by the trade-off equations modifying ratings (whereas in Family_Winner both winning and losing parties were affected).

4.4 Asset Negotiation Example

This sub-section will review the process and advice about a Family Law case trialed on AssetDivider. The aim of this exercise is to demonstrate the system's operation in practice. Table 1 below describes a divorce case provided by RAQ: we move directly to the numerical values translated from the linguistic variables.

Suggested percentage split: "40/60 (where 40% to Husband and 60% to Wife. This means Husband is entitled to 108,000 and wife 162,000". Intake details of the negotiation are shown in Fig. 1.

The next screen that appears lists the issues in dispute (Fig. 2), their ratings and the allocation summary, which is filled in appropriately when the user clicks button

Table 1 List of assets

Item name (including assets and debts)	$ Value	Husband's ratings	Wife's ratings
House mortgage	350,000 (200,000)	30	60
W car	10,000	0	10
Boat	30,000	20	0
Shares	50,000	30	10
Cash (savings)	20,000	30	20
H Car	10,000	10	0
Totals	270,000		

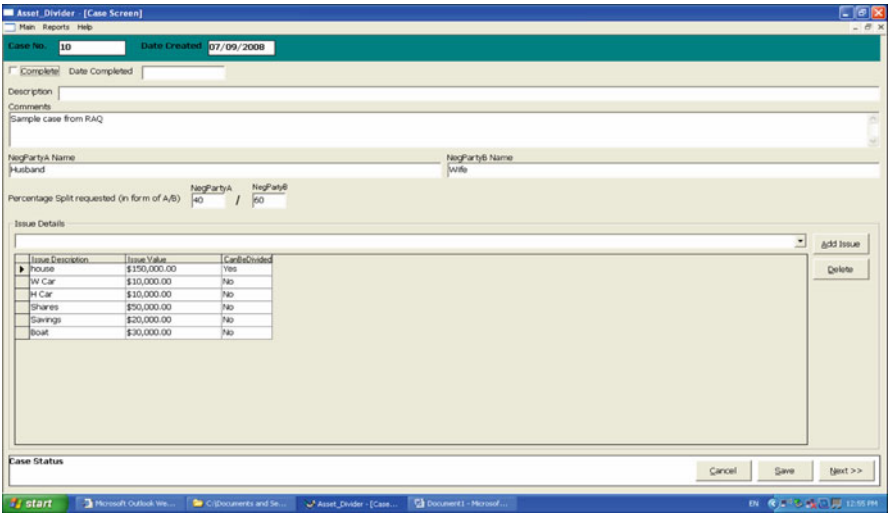

Fig. 1 Intake screen

"Calculate allocations". In the Allocation Summary table, we can see that the ratings for Husband (party A) and Wife (party B) are scaled to add to 100 in columns ComputedValuePartyA and ComputedValuePartyB, respectively. It is then these ratings that are used to drive the allocation.

The allocation, taking into account each party's' priorities (ratings) and percentage split is summarized below (Table 2):

In analysing the case, we can see that husband (Party A) wanted the shares (27.50), then the house (25) and savings (23.49). He valued the boat at 16.67, his car (Husband's car) 8.68 and W(wife's) car 0. Given he is entitled to only 40% of the total, we consider he would be happy with his allocation of the boat, shares, cash saving and his car (H car). The wife valued the house quite considerably at 55.56. Obtaining the house was her priority above all else. The rest were valued quite minimally, with shares at 18.52, boat 11.11, her car (W car) and H car at 3.70 each and cash savings at 7.41. We believe she would also be happy with her allocation, as she was given the house (of utter importance) and her car (W car).

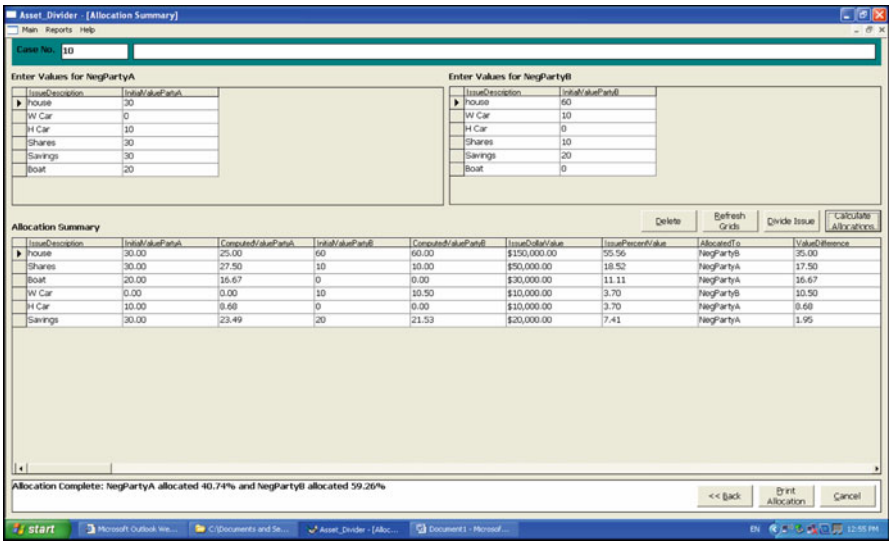

Fig. 2 Allocation summary screen

Table 2 Allocation list for husband (party A) and wife (party B)

Husband's list of allocated items	Husband's $ value of each item	Wife's list of allocated items	Wife's $ value of each item
Boat	30,000	House	350,000
Shares	50,000	W Car	10,000
Cash	20,000	Mortgage	200,000
H car	10,000		

Totals for Husband: $110,000; and wife: $160,000; that is very close to the 40/60 split requested

The reason why Husband and Wife were both allocated the cars was because each valued each other's at 0. As long as their allocation did not violate the percentage split allowance, there was no real negotiation about who wanted the cars.

5 Multi-agent Negotiation Support Architecture

IMODRE, which stands for integrated online dispute resolution environment, was developed to provide more comprehensive negotiation support than that given by Family_Winner and AddetDivider. IMODRE was developed using the JADE[8] agent development platform, and is configured to run on a Tomcat server using MySQL[9] and JDBC[10] for database connectivity. One agent uses a Bayesian Belief Network expertly

[8] http://jade.tilab.com/. Last accessed 2 January 2010.

[9] http://www.mysql.com/. Last accessed 11 January 2010.

[10] http://java.sun.com/javase/technologies/database/. Last accessed 11 January 2010.

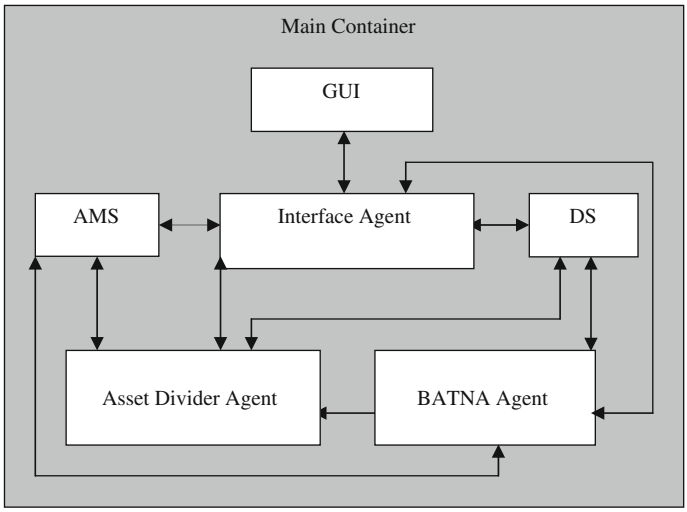

Fig. 3 Multi-agent negotiation support architecture

modeled with knowledge of the Australian Family Law domain to advise disputants by means of a percentage property split, of their Best Alternatives to Negotiated Agreements. Another agent incorporates this percentage split into an integrative bargaining process and applies heuristics and game theory to equitably distribute marital property assets and facilitate further trade-offs.

The JADE main container also provides two special agents; (1) an agent management system (AMS) that ensures that each agent has a unique name, and allows agents on external containers to be terminated; and (2) a directory facilitator (DF) that lists services offered by agents so that other agents can find them. Agents communicate using the FIPA ACL[11] language specification. The system architecture is presented in Fig. 3.

The IMODRE architecture represents the classic master/slave architecture which in some ways may be considered contrary to the decentralized nature of multi-agent systems. It is, however, a suitable architecture for our needs because all decisions are interrelated and the negotiation process requires central coordination. The type of agent interaction is facilitative with the agents performing specific negotiation tasks and coordinating to assist disputants in reaching a negotiated settlement. The architecture is vastly different from the fully automated negotiation systems described by Fatima et al. (2009) and Oshrat et al. (2009) where agents negotiate directly with each other.

Because the system is Web based, parties are able to conduct negotiations from separate geographical locations, provided they have internet access. This is a major advantage in cases where face-to face meetings are not feasible, or where parties are located at great distances apart.

[11] http://www.fipa.org. Last accessed 2 January 2010.

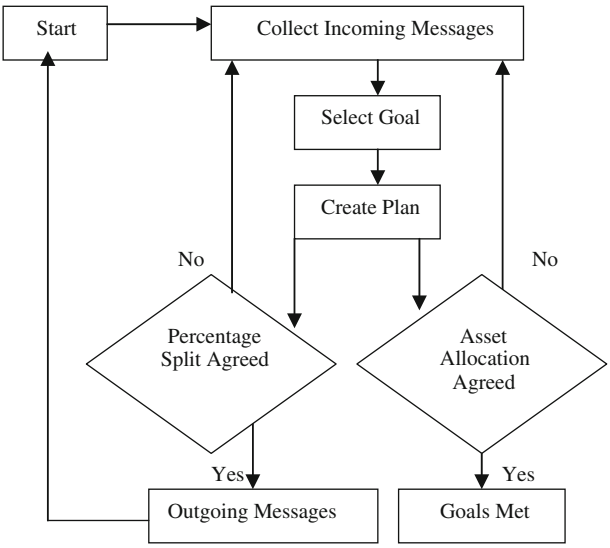

Fig. 4 Interface agent workflow

5.1 Interface Agent

The interface agent acts as the system's gateway to external resources. The agent interacts with users via a JSP[12] graphical user interface, and manages the negotiation process by coordinating multi-agent activities. It has a wider perspective of the system than the other agents in the group, creates plans and assigns tasks to individual agents in order to ensure global coherence.

The interface agent collects input parameters from the disputants. It then selects the initial goal to obtain an agreed percentage split via the BATNA agent and creates a plan to meet this goal. If the goal is not met the process starts again and a new plan is formulated based on the new input parameters it receives from the disputants. If the goal is met then the next goal is chosen, which is to allocate assets to the disputants as equitably as possible and obtain their agreement on the allocation via the AssetDivider agent. If this goal is met then the negotiation process is complete and agreement is considered to have been reached. If the goal is not met parties can re-negotiate and trade-off assets until they are satisfied with the allocation (Fig. 4)

5.2 BATNA Agent

The BATNA agent user a Bayesian belief network to infer a percentage property split. Bayesian belief networks[13] are powerful tools for modelling causes and effects

[12] Java Server Pages (JSP) technology provides a simplified, fast way to create dynamic web content. http://java.sun.com/products/jsp/. Last accessed 12 January 2010.

[13] http://www.cra.com/pdf/BNetBuilderBackground.pdf. Last accessed 2 January 2010.

in a wide variety of domains. They are compact networks of probabilities that capture the probabilistic relationship between variables, as well as historical information about their relationships. They are very effective for modelling situations where some information is already known and incoming data is uncertain or partially unavailable (unlike rule-based or "expert" systems, where uncertain or unavailable data results in ineffective or inaccurate reasoning).

Equation 1 is known as the Bayesian rule. The concept considers that event A is dependent upon event B.

$$p(\mathrm{A}|\mathrm{B}) = \frac{p(\mathrm{B}|\mathrm{A}) \times p(\mathrm{A})}{p(\mathrm{B})} \tag{1}$$

Bayes' theorem can be transformed to the following equation to account for both multiple hypothesis and multiple evidence:

$$p(H_i|E_1E_2\ldots E_n) = \frac{p(E_1E_2\ldots E_n|H_i) \times p(H_i)}{\sum_{k=1}^{m} p(E_1E_2\ldots E_n|H_k) \times p(\mathrm{H}_k)} \tag{2}$$

Toulmin argument structures can complement Bayesian belief networks by providing a mechanism for decomposing tasks into sub-tasks, and extracting claims and data items from a series of interconnected arguments.

Muecke et al. (2008), with the assistance of Australian Family Law Expert Andrew Combes, have modelled judicial reasoning, using an adaptation of Toulmin argument structures and a Bayesian Belief Network for the purpose of determining a percentage split of assets between divorcing couples. In their argument tree, a series of sub-level arguments culminate into three top level arguments that represent the three factors considered most important by the domain expert in determining the division of marital property assets. At the top of the tree is the root node, which represents the percentage property split.

With permission from Muecke et al. (2008), we were able use the structure of this argument tree to develop an agent for our NSS that provides parties with their BATNA during marital property negotiations.

The BATNA agent uses an inference method called the Recursive Conditioning algorithm. This method exploits assumptions to decompose a Bayesian network into smaller, disconnected pieces that can be solved independently. The algorithm is formalised below:[14]

- Let C be a set of variables such that the instantiated network <N,c> is decomposed into two disconnected subnetworks $< N, c >^l$ and $< N, c >^r$.
- Then

$$P^N(e) = \sum_c P^{\langle N,c\rangle}(e) = \sum_c P^{\langle N,c\rangle l}(e_l) P^{\langle N,c\rangle r}(e_r) \tag{3}$$

[14] http://www.cs.helsinki.fi/u/mkhkoivi/teaching/sum-products-fall05/presentations/parviainen.pdf. Last accessed 2 January 2010.

Table 3 Circumstances of marriage (evidences)

E_1	The wealth of the couple can be considered average
E_2	The wife in future will need more
E_3	The wife in the past has contributed more

Table 4 Three possible outcomes (Hypothesis')

H_1	60% of property awarded to wife
H_2	60% of property awarded to husband
H_3	50%

Table 5 Prior and conditional probabilities

	Hypothesis		
	$i = 1$	$i = 2$	$i = 3$
$p(H_i)$	0.45	0.35	0.20
$p(E_1\|H_i)$	0.25	0.60	0.55
$p(E_2\|H_i)$	0.80	0.40	0.65
$p(E_3\|H_i)$	0.70	0.00	0.80

where e_l and e_r are subsets of instantiation e pertaining to subnetworks $< N, c >^l$ and $< N, c >^r$.

- Queries $P^{<N,c>l}(e_l)$ and $P^{<N,c>r}(e_r)$ can be decomposed using the same method recursively.

Users are required to assert their beliefs about marriage contributions, the common pool of assets, and future needs at one level down from the root node in the argument tree. If the parties agree on all three sub-arguments, or alternatively, if the same percentage property split is inferred through different combinations of sub-arguments assertions, agreement is said to be reached and both parties are advised of the recommended percentage split.

Suppose a couple named Bob and Carol are divorcing and have both agreed that the wealth of the couple can be considered average, Carol has greater future needs, and Carol has contributed more. We therefore have the evidence shown in Table 3:

We also compare three possible outcomes represented as a set of Hypothesis:

For the given three conditionally independent evidences (Table 3) and three mutually exclusive and exhaustive hypotheses (Table 4), our family law domain expert has established the following prior probabilities for these hypothesis and conditional probabilities of observing each evidence with each hypothesis (Table 5)

Thus, by applying Eq. 2:

$$p(H_1|E_1E_2\ldots E_n) = \frac{0.25 \times 0.8 \times 0.7 \times 0.45}{0.25 \times 0.8 \times 0.7 \times 0.45 + 0.6 \times 0.4 \times 0.0 \times 0.35 + 0.55 \times 0.65 \times 0.8 \times 0.2} = 0.52$$

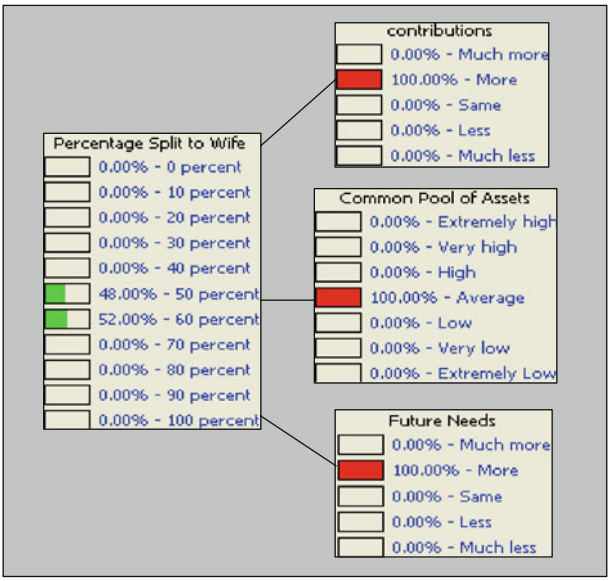

Fig. 5 Top-level assertions

$$
\begin{aligned}
&p(H_2|E_1E_2\ldots E_n)\\
&= \frac{0.6\times 0.4\times 0.0\times 0.35}{0.25\times 0.8\times 0.7\times 0.45+0.6\times 0.4\times 0.0\times 0.35+0.55\times 0.65\times 0.8\times 0.2}\\
&= 0\\
&p(H_3|E_1E_2\ldots E_n)\\
&= \frac{0.55\times 0.65\times 0.8\times 0.2}{0.25\times 0.8\times 0.7\times 0.45+0.6\times 0.4\times 0.0\times 0.35+0.55\times 0.65\times 0.8\times 0.2}\\
&= 0.48
\end{aligned}
$$

Hypothesis 1 ($H1$) is calculated to be the most likely outcome. The BATNA agent has therefore inferred that a family court judge is most likely to award 60% of the marital property to Carol should the matter be litigated (Fig. 5).

The recommended percentage split is then passed to the Asset Divider agent.

If agreement is not initially reached, users are asked if they wish to change the assertions in the nodes where disagreement exists. If this step fails to resolve the matter, parties are then prompted to make assertions at the next lower sub-argument level. This process continues until either the arguments for a branch are agreed upon or a leaf argument of the dispute is reached.

If the leaf argument of the dispute is reached without agreement, then both parties assertions for that particular node are accepted. This is demonstrated in Fig. 6 where parties are unable to agree at the leaf node 'Past Level of Employment'. The assertion 'Unemployed' and 'Irregularly employed' are therefore equally accepted and the percentage split is inferred on this basis.

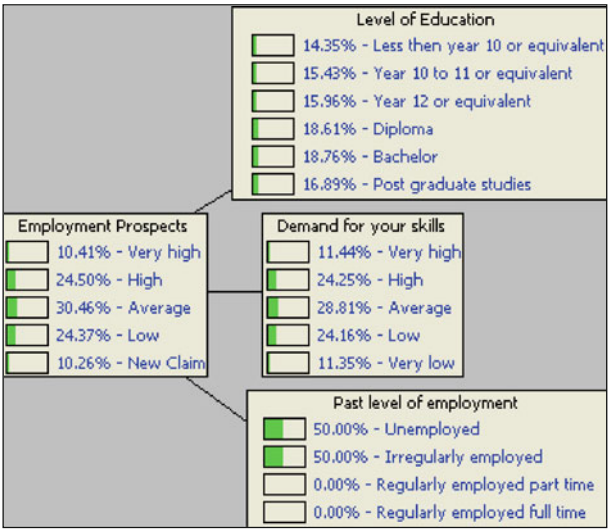

Fig. 6 Leaf node assertions

5.3 AssetDivider Agent

The AssetDivider agent uses a modified version of the Adjusted Winner algorithm developed by Brams and Taylor (1996), to divide n divisible goods between two parties as fairly as possible[15]. Adjusted Winner starts with the designation of the items in a dispute. If either party says an item is in the dispute, then it is added to the dispute list[16].

Like AssetDivider, the parties then indicate how much they value each item, by distributing 100 points across them[17]. This information, which may or may not be made public, becomes the basis for fairly dividing the goods and issues at a later stage. Once the points have been assigned by both parties (in secret), a mediator (or a computer) can use Adjusted Winner to allocate the items to each party, and to determine which item (there will be at most one) may need to be divided. Whilst disputants can probably linearly order the significance to them of all items in dispute, it is unrealistic to expect them to give a numerical value to each item. But it is not unreasonable for the users to assign a linguistic variable to each item. We use a seven point scale which can then be converted into points (Table 6):

Suppose Bob and Carol select the following terms for the issues in dispute (Table 7):

[15] See http://www.nyu.edu/projects/adjustedwinner/. Last accessed 2 January 2010 for examples and to use the Adjusted Winner software.

[16] The other party could of course give the item the value zero.

[17] In fact if the sum of the items was not 100, the numbers should be scaled. Essentially the disputants are being asked how they rank and value the items in dispute.

Table 6 Significance ratings scale

Description	Points
Irrelevant	0
Little significance	10
Marginal	20
Moderate	30
Important	40
Very important	50
Essential	60

Table 7 Unscaled ratings

Item	Carol		Bob	
	Description	Unscaled points	Description	Unscaled points
Retirement account	Marginal	20	Moderate	30
Home	Marginal	20	Essential	60
Investments	Very important	50	Very important	50
Summer cottage	Little significance	10	Marginal	20
Boat	Irrelevant	0	Important	40
Total		100		200

Table 8 Scaled ratings

Item	Scaled points		Divisible item?
	Carol	Bob	
Retirement account	20	15	Yes
Home	20	30	No
Investments	50	25	Yes
Summer cottage	10	10	No
Boat	0	20	No
Total	100	100	

Scores are then normalised to 100. Bob's total score is initially 200, thus to scale his scores, each number is multiplied by 100/200 = 0.5. Carol's score initially totals 100, so does not need to be normalised (Table 8).

The AssetDivider agent begins by assigning items to the person who put more points on them. Thus, Bob receives the home and the boat, whereas Carol receives the investment and retirement accounts. Leaving aside the tied item (summer cottage), Carol has a total of 70 (20 + 50) of her points, and Bob a total of 50 (30 + 20) of his points. This completes the "winner" phase of adjusted winner.

Because Bob trails Carol in points (50 compared to 70) in this phase, initially the summer cottage is awarded to Bob, which brings him up to 60 points (30 + 20 + 10).

The "adjusted" phase of Adjusted Winner commences now. The goal of this phase is to achieve an equitable allocation by transferring divisible items, or fractions thereof, from Carol to Bob until their points are equal.

What is important here is the order in which items are transferred. This order is determined by looking at certain fractions, corresponding to the items that Carol, the initial winner, has and may have to give up. In particular, for each item Carol won initially, the algorithm looks at the fraction giving the ratio of Carol's points to Bob's for that item:

> (Number of points Carol assigned to the item)/(Number of points Bob assigned to the item)

In the example, Carol won two items, the retirement account and the investments. For the retirement account, the fraction is 20/15 = 1.33, and for the investments the fraction is 50/25 = 2.0.

The algorithm starts by transferring items from Carol to Bob, beginning with the divisible item with the smallest fraction. This is the retirement account, with a fraction equal to 1.33. It continues transferring goods until the point totals are equal.

Notice that if the entire retirement account was transferred from Carol to Bob, Bob would wind up with 75 (60 + 15) of his points, whereas Carol would plunge to 50 (70 − 20) of her points. Therefore, the parties will have to share or split the item. So the algorithm's task is to find exactly what fraction of this item each party will get so that their point totals come out to be equal.

Thus, let p be the fraction of the retirement account that needs to be transferred from Carol to Bob in order to equalize totals; in other words, p is the fraction of the retirement account that Bob will get, and $(1 - p)$ is the fraction that Carol will get. After the transfer, Bob's point total will be $60 + 15p$, and Carol's point total will be $50 + 20(1 - p)$. Since the point totals need to be equal, p must satisfy:

$$60 + 15p = 50 + 20\,(1 - p)$$

Thus $35p = 10$ and so $p = 10/35 = 2/7$. Thus, Bob should get 2/7 of the retirement account and Carol should get the remaining 5/7, leaving each party with 64.29 points. The agent must now make a further adjustment to allocate the percentage property split it received from the BATNA agent. A universal issue in the form of a cash variable is used to make this adjustment. The person owing the cash amount is also given the option of trading a portion of one of their allocated divisible assets should they not wish to make a cash payment (Table 9).

In the example above, we make the assumption that the dollar value of items has been agreed upon before negotiations commence. Asset values could possible be decided by an independent third party or mediator. In reality, however, it is quite conceivable that a major issue in dispute may involve determining the value of the item. For example following a divorce, the husband may agree that the wife should be awarded the marital home. In this case it would be in his interests to overvalue the house (say he suggests it is worth $1,200,000) whilst it is in the wife's interest to undervalue it (say she suggests it is worth $800,000).

Table 9 Asset distribution

Item	Carol	Bob	Divisible item?
Retirement account	$150,000	$60,000	Yes
Home mortgage (net value)		($270,000–$200,000) $70,000	Yes
Investments	$160,000		Yes
Summer cottage		$110,000	No
Boat		$30,000	No
Cash variable	$95,000		Yes
Total value	$405,000	$270,000	
Percentage split	60%	40%	

We therefore need to consider strategies that allow the system to resolve such issues. One possible solution is to add an automated blind bidding feature where the program selects a dollar amount from several confidential offers or blind bids based on an agreed-upon settlement range. Cybersettle[18] is one application that uses this strategy to resolve disagreements over monetary values.

The AssetDivider agent also allows users to input negative values. This is a necessary feature because family mediation clients often have debts (such as credit card debts and mortgages) which are as much items the negotiation as assets.

There is one main difference between utility function algorithms of the AssetDiver program and AssetDivider Agent of the new system. When the allocation of an item breaches the agreed dollar value percentage split, rather than place the item back into the negotiation and continuing, if divisible, the item is now divided between the two parties in accordance with the required percentage split. If the item is not divisible, the cash variable is used to maintained the required split.

6 Evaluating Asset Divider and Future Work

Family_Winner attracted much local and international media interest including various newspaper articles, radio interviews and a win on an episode of the Australian TV Program the New Inventors[19]. Subsequently we were contacted by Mr. Shane Klintworth, director of the Queensland Branch of Relationships Australia (RAQ). Relationships Australia is one of Australia's primary providers of family counseling and family mediation services. Its Queensland branch runs some national Family Relationship Centres. These centres provide information and advice on (a) building and strengthening existing relationships; (b) early intervention and prevention services for couples thinking of separating; (c) child-friendly services for families in conflict; (d) FDR services; and parenting plans.

Mr. Klintworth saw the benefits to RAQ of a system that could enhance interest based negotiation. However, he also saw the need to emphasise the paramount

[18] http://www.cybersettle.com/pub/. Last accessed 2 January 2010.

[19] http://www.abc.net.au/tv/newinventors/txt/s1504763.htm. Last accessed 2 January 2010.

interests of the children in any system. While meeting parental desires is important, meeting children's needs is paramount. Further, especially when the divorcing couple has children, it is vital to encourage a harmonious on-going relationship between the parents.

Whilst Family_Winner promotes integrative (win–win) rather than adversarial (win-lose) solutions and is conducted through processes that are fair and are perceived by the parties to be fair, RAQ has other needs including:

- the need for decisions to comply with prevailing ethical/ legal principles (such as the rights of the child and tenancy laws);
- the prevention of further conflict through the development of clear arrangements (such as prenuptial arrangements between partners and clear guidelines for apartment owners); and
- the promotion of collaborative problem solving between parties.

The organization saw the benefits of a system that could enhance interest based negotiation and expressed interest in using an updated version of the software for their family mediation sessions. We have since been working with RAQ to develop a new methodology and software to better represent the needs of the family mediation sector.

AssetDivider is our initial attempt to meet these needs.

In late 2008 a preliminary evaluation of AssetDivider was conducted in conjunction with our contacts at RAQ, the results of which were reported in Bellucci (2008). The evaluation process resulted in several modifications being made to the original system which have now been incorporated into our new IMODRE integrated ODR environment. The determination of one's BATNA, a cash variable, acceptance of negative asset values, and an improved user interface all represent upgrades to AssetDivider.

The fact that the IMODRE system is Web based is potentially of significant advantage to RAQ. A large number of the mediations that the organization conducts are done through their telephone dispute resolution service. This service is national and thus many participating disputants are based at great geographical distances apart. A Web accessible system therefore provides a convenient mechanism for conducting mediations/negotiations in such circumstances.

When fully implemented the new system will be extensively evaluated and tested using simulated disputes involving both control and experimental groups. The control group will use conventional methods of negotiation while the experimental group will conduct their negotiations using the software. We will the analyse perceived effects that that the use of the ODR software had on the negotiation process, the difference in resulting dispute outcomes, as well as a technical analysis measuring system performance and usability. Experimental participants will comprise of postgraduate students undertaking a negotiation unit of study from Victoria University.

The use of simulations involving students as a method is a well tested and accepted methodology in this type of research across the various disciplinary and professional divides: See for example Druckman and Albin (2008) and Buelens et al. (2008). The key advantage of this approach, as in experimental studies generally, is the reduced ambiguity in specifying the relationship between key variables. Also, it is possible to closely study the details of a process, such as conciliation, which would be generally

impossible in a real life situation. Finally, it allows me to impose new strategies in the situation that is safe but very difficult to do in the real situation.

As a result of the media exposure we were also contacted by Mr. Herman Klein, director of Victoria Body Corporate Services (VBC). Victoria Body Corporate is a medium size company offering personalised management services to bodies corporate, strata title units and company share properties. A major facet of its role is the successful resolution of disputes amongst body corporate members. Because, in general, the disputants live in the body corporate (and hence in close proximity to each other) it is important that disputes be resolved so that the body corporate members can continue with harmonious relationships. With this in mind, VBC wishes to develop software that can help their managers amicably resolve disputes. Mr. Klein believes that the innovative application of NSSs will give him a marketing advantage over other body corporate companies.

We have subsequently developed a model of dispute resolution rules for condominium owners to promote constructive mediation following the resolution of disputes. We are also in the process of developing agents expertly engineered with domain knowledge of Victorian property law.

7 Conclusion

In both family law and condominium law, the disputants need to maintain relationships following the resolution of disputes. Thus, as part of a large Australian Research Council funded project[20], we developed an integrated ODR environment to house NSSs for both housing and family disputes. The paper described various negotiation strategies including bargaining in the show of the law and the notion of a BATNA, as well some tools that are available to support these strategies. We presented our previous work in developing NSS to provide some background to the research. We then demonstrated our current integrated ODR environment IMODRE, including the negotiation the strategies that we have deployed, to assist parties involved in Australian family law disputes achieve fairer negotiated outcomes.

The approach taken is to merge integrative bargaining techniques developed from argumentation, AI and game theory with a multi-agent environment where individual agents are assigned specific negotiation tasks. The type of agent interaction is facilitative with the agents performing specific negotiation tasks and coordinating with each other to assist disputants in reaching a negotiated settlement. One agent uses a Bayesian belief network and an adaptation of Toulmin argument structures to recommend a percentage property split based on a disputants' BATNA. Another agent combines this percentage split with heuristics and game theory to facilitate integrative bargaining of marital property assets. We believe that the inclusion of a BATNA in the negotiation process provides an important starting point for negotiations and allows fairer agreements to be obtained by providing a level of protection against power imbalances.

[20] LP0882328 Developing Negotiation Decision Support Systems that promote constructive relationships following disputes.

The system, which was developed in conjunction with industry partners Victoria Body Corporate Services and Relationships Australia (Queensland branch), respects ethical and legal principles and relies upon processes that are not only fair but are perceived by the parties to be fair. Apart from merely resolving disputes, we anticipate that by helping parties reach agreements that better satisfy their long term interests, the system also supports the continuation of constructive relationships following disputes.

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