Supporting Peace Negotiation with Superexpertise

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Abstract. An expert epistemology is a theory about knowledge in the expertise and includes knowledge representation, semantics, specifications, heuristics, reasoning, etc. Superexpert systems employ computer capabilities to extend ordinary human abilities, and are derived from expert epistemologies. A superexpert system, Negotiation Game or NeGame (NeG), is designed to support the Harvard Principled Negotiation model; it is illustrated by a Civilisation application which reframes the Israel-Palestine conflict as the task of negotiating a mutually acceptable civilisation. The negotiation epistemology of NeG evolved from the adversarial epistemology of eGanges (eG); both handle tasks in a user-friendly and transparent way. NeG manages hierarchical complexity of the conflict issues and differences in their subjective values, advises on cumulative scoring of Wins and Losses, and, through mathematical techniques, maximises Win-Win options. Adversarial epistemology requires four-valued logic, whereas negotiation epistemology requires six-valued logic; they share a common knowledge hierarchy, called a River.

Keywords: epistemology, superexpertise, eGanges, Principled Negotiation, quality control fishbone.

1 System of Legal Epistemology

An expert epistemology can be derived from expertise, such as legal practitioner's expertise (Gray, 2007); it can include knowledge representation, semantics, specifications, heuristics, and reasoning. Compared to human experts, computers *inter alia* can have larger memories, faster retrieval, and faster processing of the possible combinatorics of complex logic. Superexpertise uses these computer capabilities and is elicited from expert epistemology; it can be deployed to support peace negotiation.

1.1 Two Types of Legal Problems

In the legal domain, two problems for lawyers in resolving and avoiding conflicts for clients, use different but overlapping epistemologies: adversarial problems and negotiation problems. Their similar epistemological features are, firstly, the use of finite information, and secondly, their suitability for a knowledge representation based on a River paradigm which can found superexpertise. Whereas a superexpert adversarial shell, eGanges (**e**lectronic **G**lossed **a**dversarial **n**ested **g**raphical **e**xpert **s**ystem)

(eG) [Gray and Gray, 2003], uses the paradigm of tributaries joining to more major Rivers which all lead to a single River mouth (the Final result node), Negotiation Game or NeGame (NeG), a superexpert negotiation shell, uses a River delta paradigm where a single source node flows along various branches which have ends in several delta-mouth nodes.

Adversarial problems apply enforceable rules to determine a winner between opposing parties; a court case is a prime example of an adversarial problem, where the rules of law are applied to determine who wins the case. Negotiation problems attempt to resolve issues in dispute between parties in conflict, through cumulative agreement, without a predetermined enforceable rule set being applied; there may be no enforceable rule set, no recognised neutral party to enforce such a rule set, or the parties may prefer not to enforce a rule set as it could cost them more. Differences between adversarial and negotiation epistemologies arise from these distinctions.

Negotiation usually precedes adversarial resolution. However, an agreed settlement of a conflict is *prima facie* enforceable. An alignment of adversarial epistemology, such as the eG epistemology, and negotiation epistemology such as the NeG epistemology may serve the formulation of an enforceable solution. A problem addressed in this paper is how to suitably align adversarial and negotiation epistemologies in the development of negotiation superexpertise. In this alignment, NeG, is designed to provide an aid for Principled Negotiation, throughout a negotiation, that gives a precise evaluation of each point in the cumulative agreement, not just of known possible alternatives, but also of newly realised options devised during the negotiation.

1.2 Three Legal Epistemology Features

There are three features of legal epistemology that are used in an alignment of adversarial and negotiation epistemologies to produce NeG: English common law epistemology, Bologna glosses and the Harvard model of Principled Negotiation.

English common law epistemology is systematic, and from its systems, the scope for computational legal epistemology, including legal superexpertise can be identified for the design of both adversarial and negotiation aids. The common law system has developed over centuries since the Royal Courts were established by William the Conqueror in the eleventh century AD, and their Justices in Eyre went around the countryside reconciling differences in local laws. The initial task of prioritisation of local rules required a focus on reasoning to ensure consistency. Similar tasks of reconciliation might be undertaken to resolve European common law and international common law. It is very difficult to develop a system of law in isolation of the facts of disputes to be resolved; conflict is greatly various and often unforeseeable.

Once the common law was settled, its further development also depended on consistency with established rules; it became a holistic system of rules fertile for further extensions. The law was said to be found through consistent extensions, not created. The practice of law implemented and expanded its rule system as if it were a tributary structure like a River. To some extent this structure was visualised by Gray's Inn lawyer, Fraunce [1588], a Ramist, who was a Reformation forerunner of modern legal knowledge engineering [Gray and Mann, 2003]. The Ramist school of logic at the Sorbonne used graphical representations of logic, sometimes with three dimensional logic space [Ong, 1958].

In the tributary structure of a River established by case or statutory authority and implemented in legal practice, formalised rules of law can be interlocked where they share common antecedents or consequents, so expansion of the common law can be fashioned consistently by adding further rules through refinement of existing rules with further antecedents or modified consequents. Sometimes a precedent case would be an authority for more than one point. In arguing that a case is an authority, or posing a case as a similar precedent to be followed, the hierarchical or tributary positions of the points is a consideration in showing similarity or distinction.

A gloss is related information peripheral to the rules, and originates from the Bologna margin notes of the resumed study of the Roman Civil Code in the eleventh century AD. Epistemological aspects of the system of English common law and glossing are used in the design of both the adversarial shell, eGanges and the negotiation shell, NeG. eG allows for glossing of each node. Further information

about an antecedent, in a retrieved gloss, might assist the user to give informed answer input on interrogation, and also assist in the resolution of issues of law. In NeG, a gloss facility may be used to expand on issue nodes and simplify or clarify further detail, without further complicating the River graphic; nesting of graphics is used to manage large-scale River graphics, as illustrated in Figures 1 and 2.

The Harvard Negotiation Project [Fisher and Ertel, 1995; Fisher et al, 1991] produced a model called ‘Principled Negotiation' which identified seven elements: interests, options, alternatives, legitimacy, communication, relationship, and commitment. Spencer [2005, p.23-4] suggests that reframing conflict for negotiation is a communication skill. Howsoever a conflict is described or perceived, is the way it is framed. As communication, the form and substance of reframing may better support the other elements of the Harvard model. Mayer [2000, p.139] captured the resource of reframing well:

> The art of reframing is to maintain the conflict in all its richness but to help people look at it in a more open-minded and hopeful way.

In reframing, adoption of selected foci and perspectives may develop both a trust relationship between the negotiators and their commitment to resolving the dispute. Legitimacy may also be incorporated in the reframing. If the form of the reframing permits, the development of options may be assisted. The negotiation process may also allow input of subjective values for each of the parties for each of the issues, to reflect the interests, foci and perspectives of the parties, respectively.

A major element of principled negotiation is alternatives. This refers to the alternatives to the BATNA (Best Alternative To a Negotiated Agreement), a concept established in the Harvard model [Spencer, 2005, pp.33-5]. The BATNA is the alternative for the parties that requires no negotiation. Reframing may prevent any limitations on the formulation of alternatives that the BATNA presupposes; increasingly, assumptions in relational epistemologies are being questioned [Dachler and Hosking, 1995]. If better alternatives can be devised by negotiation, then the parties can be assisted by a gloss evaluation of these alternatives to show those that are better than the BATNA and exactly how.

2 Reframing: Civilisation River

An example of the delta River structure is shown in a NeG application, called Civilisation. The Israel-Palestine conflict is reframed as a task of negotiating a civilisation acceptable to both the parties. This reframing moves the conflict from a competitive to a cooperative and collaborative orientation. The definitional hierarchy of some issues to be resolved in the Civilisation River is shown in the Rivers window of Figure 1. Further definition may be expanded or adjusted during the negotiation. Figure 2 illustrates the nested nature of the River system: it is the further detail of the negotiation issue node, Environment, in Figure 1. Nesting is required as the sub-branches from the Environment node are too extensive to be seen in one window with the non-Environment branches.

In Figure 1, 'Environment' is seen to be on the same branch as 'System of law' through to 'Foreign policy'; this is the primary branch which has the Civilisation node as its encompassing node. An arrow on the branch, pointing from the Civilisation node along the primary branch indicates that the Civilisation node is the encompassing node of all nodes on the primary branch; the issues covered by the nodes on the primary branch are all sub-issues of the Civilisation issue. The primary branch is also called the Environment node branch and the 'Systems of law' node branch, etc.; sub-issues on the primary branch may be encompassing nodes on their sub-branches. For instance, the branch consisting of the 'Land tenures', 'Co-ownerships' and 'Disposition' nodes, is a sub-branch of the Environment node, as can be seen in Figure 2; there is an arrow showing the direction of flow from 'Environment' along this sub-branch. In short, a node's branch is the branch that has the node on it as a non-encompassing node, and a node's sub-branch is a branch that has the node as its encompassing node. Sub-issues which do not have sub-branches, wherever they occur, are called delta-mouth nodes, where negotiation becomes decisive.

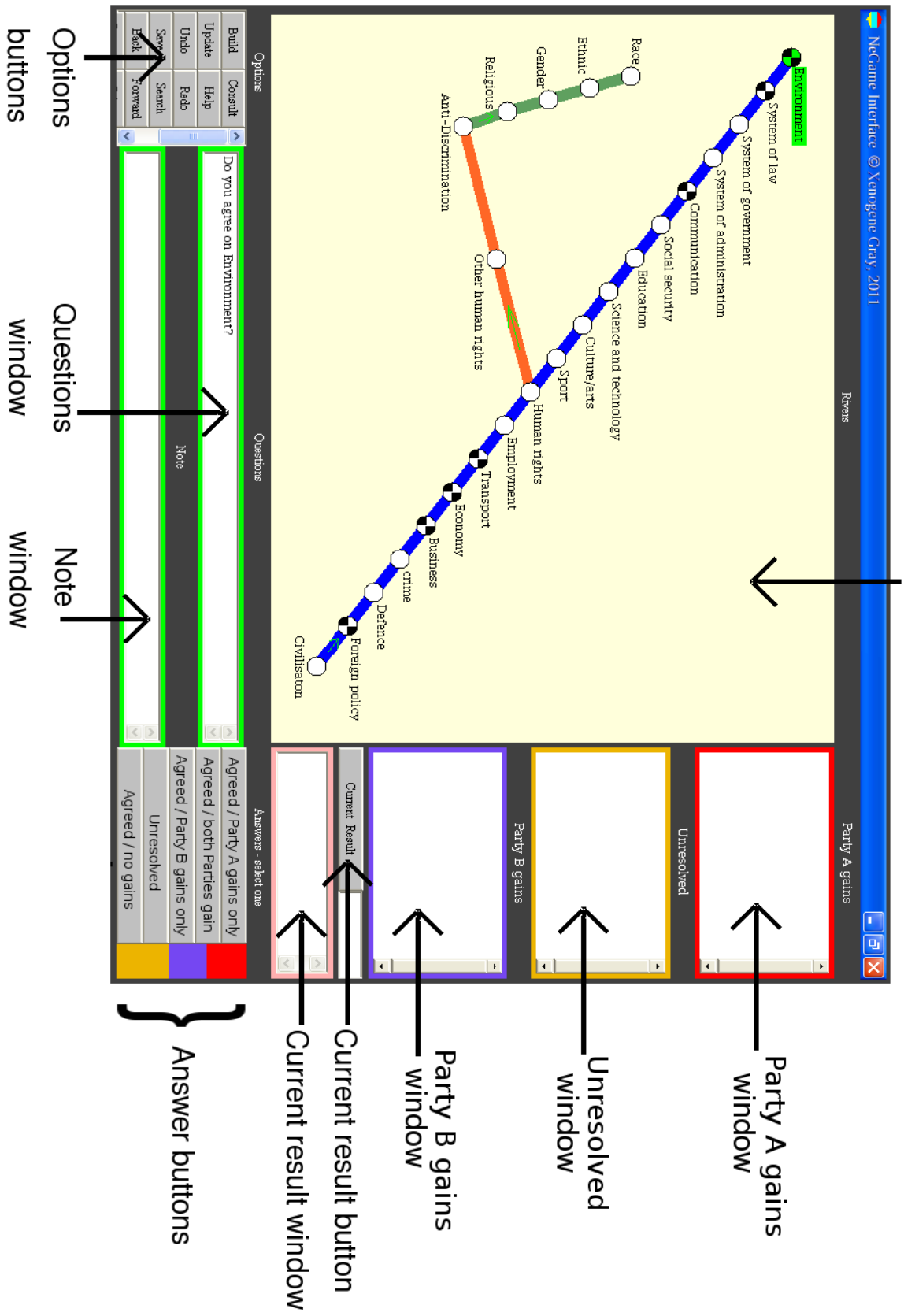


Figure 1: NeGame interface with Initial map of Civilisation application in Rivers window.

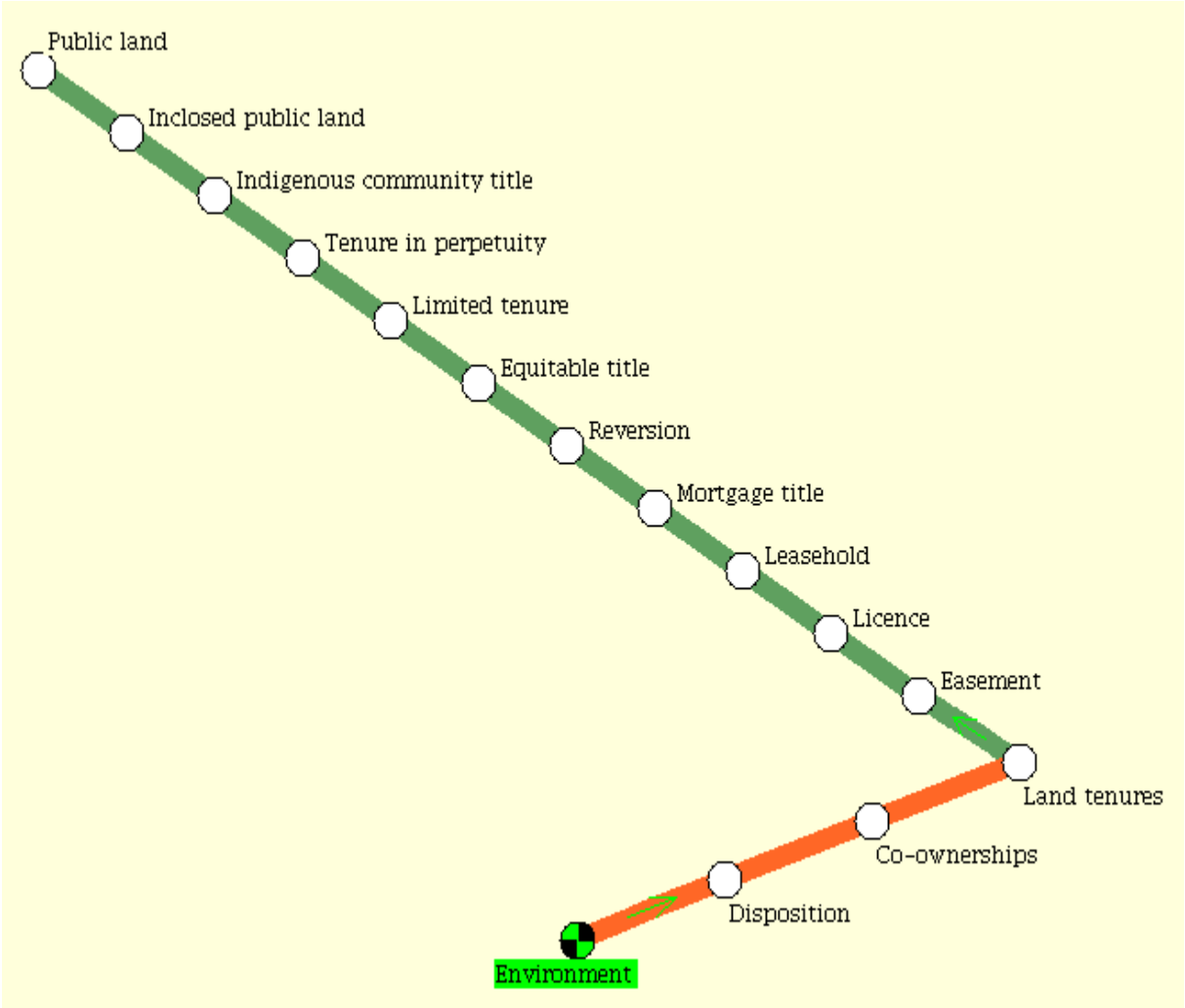


Figure 2: Submap for Environment

In Figure 2, the Environment node is the encompassing node for the branch made up of its sub-issues, and demonstrates how clusters of issues may be identified through sub-mapping. In NeG, clusters of issues and flow directions are used to simplify the normalisation of subjective values given to issues by the parties. The subjective values of each party are normalised relatively amongst the group of nodes on the same branch; each node in a branch may also be an encompassing node for another River branch, in which case the encompassing node's normalised value will be propagated along its sub-branches to aid in the fair assessment of gains. The paradigm of the delta may secure quality control in Principled Negotiation of civilisation, just as the tributary River secures quality control in an adversarial system of rules (Gray and Gray, 2011).

An agreed future civilisation could be identified as Solvilisation with connotations of a civilisation suited to the solar system, and as wise as Solomon, partly law and partly wisdom. The most famous judicial reframing of a case, perhaps the oldest, was decided by the ancient biblical Jewish King, Solomon. Two women claimed to be the mother of a baby. Solomon suggested that the baby be cut in half; the true mother relinquished her claim but, as a result, was seen to be the real mother and was awarded the baby.

In formulating the civilisation application, precedent civilisations may be drawn on, from anthropological, archaeological and sociological studies; a consensus United Nations Model might be developed on the basis of its many international agreements and conventions. Darwinian principles of

evolution [Gray, 1982, p.63] may also be taken into account in making selections from alternatives to chisel out the Solvilisation.

One Darwinian principle of evolution requires maximum diversity to maximise survival. For example, in environmental management, if Limited freehold [Gray and Gray, 2009], as an evolution of feudal preconceptions of property, is created as a new tenure option for a Solvilisation, as shown in Figure 2, this may assist resolution of territory disputes. With its potential of diversity to suit personal requirements, similar to Leasehold terms, Limited freehold might mollify the sense of permanent deprivation of land; also it might suit the requirements of the middle classes whose means are insufficient for the price of tenure in perpetuity. Further, if reversions of Limited freehold return to the state at the end of the term, there will be state assets to secure land and government borrowings for future public infrastructure construction, such as roads, railways and airports. State reversions may be resold as Limited tenure from time to time, as needed, to supplement tax revenue. Continuous reversions to the state also permit reviews of specific environmental protection covenants that run with land.

The Civilisation application also indicates a potential for development of political democracy as a system of election of civilisation negotiators and administrators, and also the potential development of litigation as a system of negotiation of diverse, consistent, personal law.

The River graphic in the NeG interface provides transparency of complex hierarchical issues and allows the creation of alternatives for negotiation at any level of the hierarchy. In NeG, issue points may be renegotiated at any time, with or without expansion of options, to achieve a civilisation bargain; options can be a continuation of the issues for negotiation. Repeated reframing might assist better understanding of each other's interests and positions, and also reveal solutions that suit or advance both parties; it may create a definition of the conflict, acceptable to both parties, that increases the potential for a common agreed solution.

In formulating a NeG application, River branches can be nested to enable as extensive a River delta as the conflict and potential solutions require; the River allows for consistent option generation as issues are refined. This resolves the difficulty recognised by Menkel-Meadow [1984, p.772]:

> … it may be impossible to represent graphically the negotiation of a complex, multi-issue transaction as a two dimensional structure, without imagining a many-planed axis with hundreds of potential coordinates.

Menkel-Meadow also asserted that adversarial negotiation inhibits the creative option generation posed in the Harvard model; a negotiation issue may be modified or added by the parties, whereas an adversarial rule can only be varied by a rule-making authority. The River paradigms are expansive and malleable for law-making and for negotiation.

2.1 Scaling up to Civilisation

It might be thought that if prospective domestic cohabitees could negotiate a home-based lifestyle with the avoidance of conflict [Gray et al, 2009 and 2007], so too could two different ethnic groups who would occupy the same homeland [c.f. Zeleznikow and Bellucci, 2011]. Scaling up from domestic cohabitation to the multi-ethnic co-adaptation of a homeland or nation, requires preliminary reframing of the issues in the negotiation of a civilisation which has satisfactory or beneficial ethnic co-adaptation.

The overarching principle of conflict resolution by negotiation is that sufficient issues must be resolved by agreement to reach a Final outcome; it is not an adversarial matter where sufficient rules of law must be applied to determine a Final outcome of the conflict.

2.2 Three Preliminaries

There are three matters to be settled before the construction of a reframed negotiation application: idiosyncrasies, exchanges, and reframing. Some parties have idiosyncratic issues that must be included in the application for resolution in their particular dispute. For example, in an unreported dispute, a spouse insisted on keeping in the bedroom, an urn of the ashes of her deceased husband; this offended her current husband and was an important idiosyncratic issue to these parties, requiring resolution. Potential exchanges that are particularly suited as *quid pro quo* between the parties, also should be sought in advance of settling the application.

3. Adversarial Superexpertise: eGanges

The eGanges River is a refinement of the quality control fishbone of Ishikawa [1985][Gray and Gray, 2011]. The base building blocks of eGanges are simple questions that, with sufficient knowledge, are mere dichotomies, e.g. “Did you drive the car?”. Each simple question is represented by a node. However, eGanges does not assume users will always have sufficient knowledge to definitively answer a question, so it allows a third possible answer, uncertain. Thus, the choice of standard possible answers is: yes, no or uncertain. eGanges also differentiates between nodes that have been answered, and nodes that have been left as unanswered. As such, each node can have one, and only one, of four possible logic values: Positive (true), Negative (false), Uncertain (evidence of uncertainty) and Unanswered (no evidence). These are epistemic logic values of the adversarial domain. When dealing with the processing of the logic values, it is appropriate to think of these four logic values as being a complete lattice [Blyth, 2005], with a logic ordering whereby:

positive > unanswered > uncertain > negative

This means that the logic value of Positive is logically 'greater than' Unanswered, which is logically 'greater than' Uncertain, which is logically 'greater than' Negative.

The eG epistemology uses this four-valued logic to resolve who wins the adversarial dispute, as each value can result in a different outcome. In a legal case, if a matter is unknown, it may be unknown due to no evidence (unanswered); alternatively, it may be unknown due to evidence of uncertainty (uncertain). This distinction indicates the further evidence required. If there is a final result of uncertain or unanswered, the distinction also assists a court to rule on the evidence, and reasons for the resolution may be recorded.

The use of multi-valued logics was posed by Lukasiewicz [1920], and extended by Kleene [1952], Belnap [1976], Ginsberg [1992], Fitting [1992], Gray and Gray [2003], and Majkić [2004]. The distinction between the two types of unknown is epistemically significant and was introduced by Gray and Gray [2003], followed by a more detailed semantic analysis of an equivalent four-valued logic by Majkić [2004].

3.1 Tributary Rivers: Graphical Rules

eG nodes are linked together in single lines as tributaries that form a River system. Each River system has only one Final consequent node, but may have many antecedent nodes and interim consequents. A consequent node is at one end of a tributary, and is differentiated from the antecedent nodes of the tributary by an arrow on the tributary graphic that points to it; this is the inference arrow in the rule. Both antecedents and consequent nodes bear questions.

An eG River is a graphical representation isomorphic to a four-valued logic Horn clause system and shows the hierarchical nature of the rules; each tributary of the River is a rule and the rules are interlocked where they share the same antecedent or consequent. Rules with the same consequent

indicate a disjunction; there are alternative ways of establishing the consequent so that the tributaries may appear as a fan.

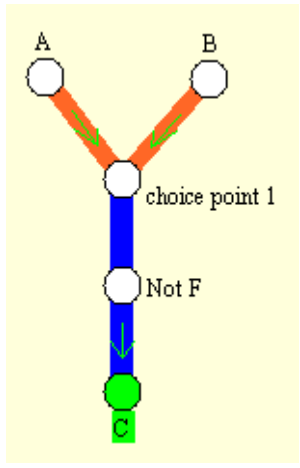
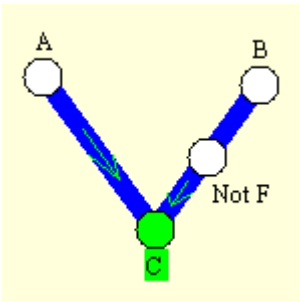
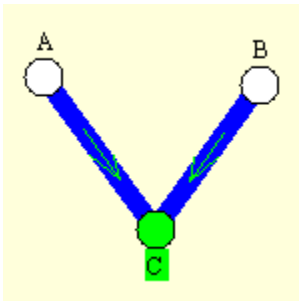
In Table 1, the leftmost eG River graphic shows three River tributaries (Horn clauses) linked together into a single River system. The three Horn clauses are:

1) 'choice point 1' ¬ A
2) 'choice point 1' ¬ B
3) C ¬ 'choice point 1', 'Not F'

Together, 1 and 2 constitute a fan with the common consequent, 'choice point 1' (some other node label could be used, e.g. D). At this choice point there is a choice of alternative rules to establish a logic value, or one of the four logic values can be directly given; also the user can choose not to answer, in which case the default logic value is unanswered. Possible selections raise a multitude of user alternatives, which increase exponentially with increases in the nodes and fans of a rule system. eG superexpertise shows the current results as each selection is made, making adjustments if the selections are changed, irrespective of where they are changed, and producing the cumulative results of a selection consultation process. An eG River can be as extensive as the rule system requires, and will be processed superexpertly as required.

With multi-valued Horn clauses, the logic value of the rule head (conclusion) must be kept greater than or equal to the logic value of the logic value of the rule body (antecedents) in order to prevent inconsistencies; e.g. if the body is found to have a logic value of positive, then the rule head must have a logic value of positive. The eGanges heuristics go further by ensuring decidability which is captured in the truth tables of Table 2 and Table 3.

Table 1. Comparison of eG Rivers and equivalent AnsProlog programs.

		
C ¬ A, **not** F	C ¬ A	C ¬ A
C ¬ B, **not** F	C ¬ B, **not** F	C ¬ B
¬C ¬ F	¬C ¬ F, **not** A	¬C ¬ F, **not** A, **not** B

Column 1 of Table 1 shows the case where **not** F must be explicitly included in the River as it is dominant over both A and B. In the second column **not** F only dominates B. For the third column, **not** F is an unnecessary node as the eG heuristics ensure C is unanswered by default while there is a chance of an upstream making it true. However, once there is no chance for C to be true from an upstream (in this example, both A and B are established as false), C becomes false by the eG heuristics, thereby fulfilling the (¬C ¬ F, **not** A, **not** B) rule by default.

Table 2. Disjunctive eG Truth table for two rules: (C ¬ A) and (C ¬ B)

	A=Negative	**A=Uncertain**	**A=Unanswered**	**A=Positive**
B=Negative	C=Negative	C=Uncertain	C=Unanswered	C=Positive
B=Uncertain	C=Uncertain	C=Uncertain	C=Unanswered	C=Positive
B=Unanswered	C=Unanswered	C=Unanswered	C=Unanswered	C=Positive
B=Positive	C=Positive	C=Positive	C=Positive	C=Positive

Table 3. Conjunctive eG Truth table for rule: (C ¬ A, B)

	A=Negative	**A=Uncertain**	**A=Unanswered**	**A=Positive**
B=Negative	C=Negative	C=Negative	C=Negative	C=Negative
B=Uncertain	C=Negative	C=Uncertain	C=Uncertain	C=Uncertain
B=Unanswered	C=Negative	C=Uncertain	C=Unanswered	C=Unanswered
B=Positive	C=Negative	C=Uncertain	C=Unanswered	C=Positive

The symbols A, B and C used in Tables 2 and 3 can represent literals, or in the case of the antecedents (A and B), they can also represent conjunctions of literals. As the multi-valued Horn clause rules may combine to form a disjunction (fan) of conjunction antecedents (River tributary), so De Morgan's laws of logic apply; effectively, the contradiction of Positive antecedents in conjunction is a disjunction of these Negative antecedents in a fan. This is shown to be embedded in the three examples in Table 1. De Morgan's laws considerably extend the combinatorics that is automated as eG superexpertise. Any formula of overlapping rules can be represented by a River system.

Usually an antecedent in one rule, such as a mainstream rule, is a consequent in another rule, such as a consequent in a secondary stream that particularises an antecedent on the mainstream. Reasoning flows downstream, following the inference arrows of the sequence of rules, as shown in Table 1.

The River rules contain the antecedent nodes that represent four-valued logic predicates. Each logic predicate is captured in a yes/no/uncertain answerable question, shown in the interrogation system in the eG interface, which is similar to the NeG interface in Figure 1. In eG, when a question is answered by the end user, the answer input becomes a logic literal. For example, “Were you informed of the terms of the contract?” becomes a logic literal when the two semantic terms “you” and “the contract” are implicitly grounded by an end user's answer.

Explicit negation is embedded into the nodes' answers in eG; for example, “Were you uninformed of the terms of the contract?” is the negative literal related to the above literal. The nodes, River structure and processing heuristics hide the *not by default* aspect nodes, as they do not need to be explicitly shown in the River system given how intuitive it is to work them out. Shown in Table 1 are the eG Rivers related to three possible consistent AnsProlog programs. They illustrate the management of disjunction in eG rules. A sample finance law application can be trialled at: www.grayske.com/FinLawTrial/index.html

4. Negotiation Superexpertise: NeG

Rather than representing a rule system and the extensive complex choice in its application, a delta River in NeG is used to graphically represent a hierarchical order of the issues to be negotiated and the complex choice of subjective values in relation to available selections. The delta structure arises from a breakdown of the conflict into its component issues, sub-issues and so on. Each issue is represented by a particular node, with the more detailed aspects of that issue (i.e. its sub-issues) represented in a River branch (a collection of nodes); the River branch is initiated by an issue node called the encompassing node. The nodes detailing the sub-issues of their encompassing node are in a sub-branch of the branch that contains the encompassing node as a sub-issue; a hierarchical River structure is formed from these node overlaps. This makes NeG's delta River layout structurally similar to the tributary River system of eG, but eG's antecedent nodes are replaced by NeG's sub-issue nodes, and the eG consequent node is replaced by NeG's encompassing node; in NeG, the same node can be both a sub-issue node in one branch and the encompassing node for another branch. In NeG, there is an overlap of sub-issue nodes and encompassing nodes, whereas in eG there may be an overlap of antecedents and consequents in different rules.

eG may have disjunctions where two different rules share a common consequent. However, generally NeG does not have disjunctions, since its task is to proceed through each issue sequentially to see if it can be agreed; in NeG, de Morgan's laws are not relevant. Notes may be made in the NeG Notes window to record any agreement on disjunctions for the purpose of constructing a final enforceable agreement as an eG River.

For NeG, the subjective valuations of each node by each party, flow in the opposite direction to the logic values flow in eG. This means the subjective values flow from the encompassing node 'down' the delta River sub-branches, as shown by the arrows in Figures 1 and 2 which point away from each encompassing node. As opposed to this, in eG the logic arrow points towards the consequent node, in accordance with the inference arrow in the rule. This reversal of the flow makes NeG's River paradigm like a River delta, where a single River source flow is divided among several delta-mouths; the conflict is divided for various and several foci and treatment in negotiation. eG's paradigm is several various logic sources flowing together and eventually to a single common outlet.

NeG nodes deal with two aspects of an issue: 1) its relative importance to both parties, and 2) who wins on the issue. The nodes on a delta branch are all related as the issues further detailing the branch's encompassing node issue, so all of a branch's issues need to be given a relative weight with respect to the other issues on the same branch. Once all the nodes on a single branch have been given their normalised relative valuation, by both parties, then the gains of each party can be determined by assessing who wins for each issue, given the relative subjective weights of each party.

Subjective values given must be numerical but there is a range of different numerical attributions that may be used by each party e.g. a value out of 10 maximum, or a percentage value rating out of 100. As long as the value is numerical, it can be normalised for the purpose of assessing relative gains and losses subjectively.

For example, the node 'Human rights' in Figure 1 has two more detailed aspects of the issue of human rights listed in its sub-branch, namely 'Anti-discrimination' and 'Other human rights'. Other issues that detail 'Other human rights' may be added in a new sub-branch as the draft application is further developed. Each party may differently value each of these sub-issues, using different numerical indicators. It is mainly the nodes with no sub-branches that are in contention; these are called delta-mouth nodes and are the most detailed sub-issues in the issue hierarchy. When a delta-mouth node is answered, with normalised subjective valuations of both parties, and one of the six sorting values agreed by both parties, it is placed in the appropriate feedback window as follows:

1) If a 'Win/Win' resolution is agreed, the label of the node appears in both the 'Party A gains' and the 'Party B gains' windows with '(Win-Win)' before the label.
2) If a 'Party A gain' resolution is agreed, the label of the node appears only in the 'Party A gains' window.

3) If a 'Party B gain' resolution is agreed, the label of the node appears only in the 'Party B gains' window.
4) If a 'Lose/Lose' resolution is agreed, the label of the node appears in the unresolved window with '(Lose-Lose)' before the label.
5) If an 'Unresolved' value is assigned to a node by the parties, the label of the node appears in the unresolved window.

Each node is given a fraction of each negotiating party's total normalised valuation. When a node is listed as a gain for that party, their valuation for that node is added to their total gains. As the negotiation proceeds, issues may be resolved cumulatively and the current gains for each party can be accessed at any time to see if there is an acceptable bargain. If each party gains more than 50% of what they value, there may be a fair basis for a bargain to be agreed. While a party might not gain on a specific node, NeG will record these losses, and this can be used to justify that party gaining on other issues they value as more important. Eventually, a net Win-Win for both parties may be agreed.

The NeG epistemology uses a six-valued logic, for two parties, to resolve a dispute. These six values cover all possibilities and are shown in Table 4. NeG gives a choice of five answers, as shown in Figure 1; both parties must agree on their single joint answer, or select the unresolved option. There is a sixth default value representing no answer (incomplete), where no answer is given.

As can be seen in Table 4, there are a finite number of possible states of an issue, and these states range over more than a single dimension of concern; there is the dimension of whether Party A gains, and a separate dimension of whether Party B gains, etc. Compacting all the possible states into a one dimensional value assignment eases processing both by the computer (with the use of appropriate multi-valued 'truth tables') and potentially by the user.

Table 4. NeG possible value states

	Party A gains, Party B gains	Party A gains, Party B loses	Party A loses, Party B gains	Party A loses, Party B loses
Both parties agree, Discussion complete	Win/Win	Party A gain (Zero-sum)	Party B gain (Zero-sum)	Lose/Lose
No agreement, Discussion complete	Unresolved	Unresolved	Unresolved	Unresolved
Discussion not yet complete	Incomplete	Incomplete	Incomplete	Incomplete

4.1 Normalisation of subjective values

The mathematical technique of normalisation is adapted in NeG to ensure fair assessment of relative gains of the parties, given their respective subjective values. Parties are free to give to each issue whatever subjective numerical value they choose, respectively; whatever values are given for each node in a branch, NeG will sum the total and calculate the proportion of the sum for each node. Each node may be subjectively valued differently to the others, and differently by each party. Once every node on a branch is given a subjective value by both parties, then the sum of the subjective values of each party is used to mathematically divide that party's value of every node on the branch. The division ensures that the sum of these normalised values equals 1 for each party; normalised

comparison of the values of each party for each node is then possible and gains can then be allotted and compared. It is likewise for other branches.

Since NeG uses a River hierarchy to order the issues to be negotiated, once every node on a single River branch is given a subjective value by each party, then the values of that River's nodes can be normalised, and the relative weightings by each party can be calculated for each node; a normalised node weighting then applies to any sub-branch of each of those nodes. In eG, according to its four-value truth tables of Table 2 and Table 3, the logic values flow down stream; for instance, a conclusion node is Positive if all the nodes in one of its upstreams are Positive. However, in the NeG delta River, the subjective values of the negotiators flow in the opposite direction, away from the encompassing node, as a downstream sub-branch.

As in eG, the number of nodes in NeG and the alternative possible values that might be given to each node, produces a multitude of alternative possible situations that might be negotiated. Normalisation of the subjective values reduces the subjective numerical alternatives that might increase this multitude of choices exponentially. At the same time, normalisation manages extremely complex fractional differences to cumulatively assess relative gains and losses. With the aid of superexpertise, fractional proportions in a large, complex conflict may narrow differences between the parties consistently with their large subjective differences.

For example, in Figure 1, the node 'Human rights' is one of 18 nodes on the primary branch of the delta. 'Human rights' has a sub-branch containing the nodes 'Anti-discrimination' and 'Other human rights'. If the negotiating parties give 'Human rights' the same normalised subjective value, compared to the other nodes on the primary branch, of 0.05 then this is the weighting factor for both parties when determining the net weighting for all sub-branch nodes of the encompassing 'Human rights' node.

A node's weighting factor is the normalised value of all its upstream encompassing nodes in the hierarchy multiplied together. For instance, suppose that one party (P1), following the normalisation calculation, gives a normalised subjective fraction of 0.6 to 'Anti-discrimination' and therefore 0.4 to 'Other human rights'. This means for P1 that 0.05 (from 'Human rights') x 0.6 (from 'Anti-discrimination') = 0.03 propagates up the 'Anti-discrimination' sub-branch as P1's weighting factor of 0.03, which will be multiplied by the normalised fraction of every node in this sub-branch to determine each node's true relative valuation.

In summary, a delta-mouth node's true relative valuation equals its normalised fraction multiplied by its encompassing node's weighting factor. The sum of all the delta-mouth nodes' true relative valuations is equal to one for each party. Each party's true relative valuation for any delta-mouth node may be different, and this means there is a fractional difference between the parties' valuations. This difference can be used to provide both parties with more than half their total valuations.

Continuing the example, if P1 values each of the 'Race', 'ethnic', 'gender' and 'religious' nodes equally, then each node has a normalised fraction of 0.25, which gives a true relative valuation of 0.25 (from the normalised fraction) x 0.03 (from the weighting factor) = 0.0075 for each of these nodes. The true relative valuations of the 'Other human rights' delta-mouth node for P1 is 0.4 x 0.05 = 0.02. These true relative valuations for P1 are the basis for comparison with the true relative valuations of the other party (P2).

Suppose P2 gave a normalised fraction of 0.4 to 'Anti-discrimination' and 0.6 to 'Other human rights', and normalised values for 'Race' of 0.3, 'Ethnic' 0.3, 'Gender' 0 and 'Religious' 0.4. This means P2's true relative valuations are:

- 0.6x0.05=0.03 for 'Other human rights'
- 0.3x0.04x0.05=0.006 for 'Race'
- 0.3x0.04x0.05= 0.006 for 'Ethnic'
- 0x0.04x0.05=0 for 'Gender'
- 0.4x0.04x0.05= 0.008 for 'Religious'

As such, P2 values 'Religious' more than P1 (0.008 > 0.0075), but P1 values the other three River issues more than P2 (0.0075 > 0.006 > 0).

There are two reasons to propagate weighting factors downstream. The first reason is to ensure that the sum of all the delta-mouth subjective valuations by any one party always sums to 1; this constitutes normalisation. Doing this ensures that a true relative valuation between parties can be performed; if P2 values 'Other human rights' relatively more, compared with every other delta-mouth issue in the entire delta system, than P1, then, in the negotiation, P2 gains more relative valuation from being assigned 'Other human rights' than P1 would gain.

In the above example, P1's valuation for 'Other human rights' is 0.4 x 0.05 = 0.02, whereas P2's valuation is 0.6 x 0.05 = 0.03; therefore, if only one party can win this issue, giving this delta-mouth issue to P2 increases total net gains that apply to both parties and is therefore reported accordingly by NeG. This is because P2 getting 'Other human rights' gives out 0.03 in the negotiation, whereas P1 getting it only gives out 0.02. Similarly, agreement to give 'Religious' to P2 results in a P2 gain of 0.05 x 0.4 x 0.4 = 0.008, whereas P1 will only lose 0.05 x 0.6 x 0.25 = 0.0075 if a Win-Win gain can not be determined. However, the gain here is smaller than the gain for 'Other human rights'.

The objective of the combinatorics is to have both parties gain more than half of their total for a Win-Win result. Thus, by giving P2 the above two delta-mouth issues, and giving the other three delta-mouth issues to P1 means:

P1 gains 0.0075+0.0075+0.0075 = 0.0225, and loses 0.0075+0.02 = 0.0275

P2 gains 0.008+0.03 = 0.038, and loses 0+0.006+0.006 = 0.012

This is not as fair as giving all 'Anti-discrimination' issues to P1 and all 'Other human rights' issues to P2, which would result in:

P1 gains 0.0075+0.0075+0.0075+0.0075 = 0.03, and loses 0.02

P2 gains 0.03, and loses 0+0.006+0.006+0.008 = 0.02

The second reason to propagate weighting factors downstream is to calculate gains as soon as possible, instead of requiring the parties, before negotiation can begin, to assign values to all the detailed issues (in order to normalise the values); the parties can assign values simply to encompassing nodes and then know relatively how much of their valuation will be devoted to the more detailed issues downstream of the encompassing nodes. The parties' values are not permanently locked in, and they can change their relative values over the course of the negotiation. However, each change a party makes will affect the net values of other branches, as their values are always normalised. The calculation of values for the issues also provides a calculated assessment of alternatives to the Best Alternative To a Negotiated Agreement (BATNA).

The normalised fractions for each node, multiplied by the weighting factor gives values for each party; the combination of the agreed value assignments enables NeG to calculate the respective gains of both parties: when a party agrees to gain on a delta-mouth issue, their valuation of that issue is added to their gains total. Pressing the Current result button will result in NeG giving, in the Current result window, the total gains, thus far, for both parties.

4.2 Advantages of River Hierarchy for NeG

In the NeG River, where there are no disjunctions, clusters of issues can be used to simplify the normalisation of the subjective values given to issues by the parties. These subjective values flow down the delta River branches so that a grouping of issues can be normalised relative to other groupings, as a matter of fair assessment of gains. The hierarchy of issues allows the creation of alternatives as an addition for negotiation at any level of the hierarchy.

The advantages of hierarchically ordering the issues into a River structure are four fold:

1) Valuing all the detailed issues can be postponed by first only valuing the encompassing nodes that represent a larger collection of issues - while still enabling value normalisation of all or some of the detailed issues to be discussed;

2) The value propagation enables all branch issues to be normalised and dealt with, without necessarily affecting the valuations of other issues that are not in the same branch of the River system.

This should help with the development of alternatives, as the current delta-mouth nodes might be replaced with agreed further possible sub-branches, without disrupting agreements in other branches and the relationship of trust built up between the parties in these previous negotiations;

3) The grouping of issues into more detailed issue organisation via branches will help clarify interests, options in the issues, and agreed packages of options;

4) The use of a quality control representation of issues like the Ishikawa fishbone, should provide legitimacy and foster commitment of the negotiators, as well as provide a means of communication to improve the relationship between the negotiators. Once a Win-Win agreement is settled, the parties may proceed with further elaboration of the agreement, in accordance with any notes they have recorded in the Notes window, to produce a binding eG River of rules or law to deal with future issues of potential conflict. Tolerance of diversity may be created by fans of disjunctions in an eG River.

4.3 Compromises and Trade-offs

Negotiation generally involves compromises and trade-offs. In negotiating over a collection of issues, the values of each party may differ sufficiently so that both parties can obtain more than half of their subjective values: this situation is called a win-win situation. The example of section 4.1 showed how both party P1 and party P2 could get 0.03 of their true relative valuation while only loosing 0.02 due to the differences in their valuations. The negotiation may still have an opportunity cost to it, but provided all parties perceive themselves as better off than they were, the outcome is a potential win-win situation (both parties gain).

There are at least five ways to achieve a win-win result:

1) subjective values on trade-offs result in both parties perceiving they have gained;
2) one party giving up something with negative or no value (eg a piece of 'rubbish'), that is valued by the other party (“one man's trash is another man's treasure”);
3) sharing information that adds value;
4) time sharing;
5) both agree to the same usage/option

An example of a valuation Win-Win scenario is where a person values food more than the money a shop wants for the food. By exchanging money for the food, the person can get something more valuable to that person than the money, namely something to eat. By exchanging the food the shop-keeper gets something more valuable, namely more money than it cost to buy the food from the wholesaler. The exchange has left both parties better off, so they have both gained from the exchange.

If one party gives a zero or negative value to something, then that party would not be worse off by letting someone else have it; in netting wins and losses, they would in fact be better off if they gave an item a negative value, i.e. considered it rubbish because they would not lose if it was awarded to the other party but the other party would win if they obtained it.

Information itself can have value; for instance, information that makes a manufacturer more efficient can result in greater returns, so the manufacturer would still be better off giving up some of the extra profit from the greater efficiency, provided the total net profit is larger than it was without that information. Alternatively, spreading useful information could indirectly benefit a person without a material cost; for example spreading information about cancer genes may lead faster to a cure for cancer, which could save the life of the person who spread the information.

As there is a limited number of things people can do, and places they can be, at any one time, they won't necessarily use things they value all the time. Thus, time sharing can potentially be a tool for negotiation.

The easiest win-win situation is where everyone agrees that the same thing should be implemented. For example, if everyone agrees no one should be allowed to kill another person, then it is a Win-Win situation [Raiffa, 1982]. Similarly, if it is agreed that a Jewish marriage should be equally available as a Muslim marriage, this may be a Win-Win decision.

It is not always clear how to achieve a Win-Win situation. However, such situations might be resolved by introducing new options such as compensation, or possibly by reframing the problem to see what changes in consequences result from a different assignment.

Negotiators generally want to be better off, though of course humans do not always behave rationally, and may be prepared to suffer a loss in order to impose a loss on another, as a form of retribution, or to push for a better final outcome. The fundamental question is: how much is a party prepared to give up to make gains, and is it enough to satisfy the parties that a fair outcome has been achieved.

Some issues have mutually exclusive solutions i.e. only one party can gain from the solution, for example the allotment of particular property that can not be shared. Mutual exclusivity is a matter of negotiation epistemology for further study that is outside the scope of this paper. Subjective values for mutual exclusivity, relative to shared solutions, and the implication of differences upstream for each that may vary depending on who gains, will be considered in subsequent work.

5. Conclusion

The user-friendliness of eG that is maintained in NeG, allows quick construction and alteration of a River system and its glosses. This permits the civilisation application that is to be negotiated, to be fully expressed and particularised, in an ongoing way, as suggested by the Harvard model.

NeG monitors progress of a negotiation and the cumulative production of agreement or specific lack of it, with current assessment of the gains of each party, that is available at any point in the negotiation. The parties may record the substance of their negotiations in the Notes window below the Question window. In NeG, the subjective value input of both parties is also available as gloss information, and summarised in the Current result window.

The superexpert model of negotiation posed in this paper employs computing capability to support the Harvard model of Principled Negotiation: extended memory, faster retrieval, specification of factors that determine possibilities and faster processing of consequent combinatorics, multi-valued logic, subjective differences that maximise alternative Win-Win options, and monitoring cumulative agreement and changes. Quality control of subjective valuations is achieved through hierarchical graphical representation and normalisation which also moderates relative valuation. The use of NeG as a technological aid, is illustrated by the Civilisation application which falls into the Harvard model of Principled Negotiation as communication. The Civilisation River allows introduction of new options through its provision for further issues and hierarchical tributary structure. NeG provides only for two party conflicts, but the design could be extended for multi-party negotiations.

NeG is designed consistently with common law epistemology and Bologna glossing to assist formulation of an enforceable resolution of the conflict; it enhances all seven aspects of Principled Negotiation. The use of a quality control representation of issues should reinforce legitimacy and foster commitment of the negotiators; as a means of complex communication and processing, it should improve the common understanding and relationship of the negotiators. The communication system of NeG assists the management of clusters of issues in a broader hierarchy as a framework for identifying delta-mouth issues which are decisive, and for expanding options at any level of the hierarchy; this assists deconstruction of complex conflicts and may reveal ways to find Win-Win solutions.

In processing Civilisation, the user-friendly NeG interface obtains instructions according to its six-value sorting requirements, and receives input on the subjective values of the parties which reflect their relative interests. Mathematical normalisation of subjective values, and the propagation of those values lends legitimacy by providing an objective metric of fairness for proposed negotiation solutions. NeG processing of each answer input simulates sorting according to its six-value logic and thereby monitors cumulative agreement in the negotiation with combinatoric processing of subjective values. Feedback throughout interrogation appears in windows that monitor cumulative relative gains of the parties and unresolved issues. This is a basis for fostering a trust relationship between negotiators and their commitment.

TechnoFuturist, Hinssen [2010, p.195] quotes Douglas Adams' response to a question at a conference as to how the new technology might affect several industries:

> This is like a bunch of rivers, the Amazon and the Mississippi and the Congo asking me how the Atlantic Ocean might affect them … and the answer of course is that they won't be rivers anymore, just currents in the ocean.

A similar view might be taken of the affect of the eG and NeG Rivers entering human life.

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