Discontinuity-Free Decision Support with Quantitative Argumentation Debates

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Extended Abstract

The representation of decision problems is an extremely challenging task, especially when these problems are *wicked*, namely they rely on incomplete or conflicting knowledge, they involve several stakeholders with conflicting views and they are closely linked with other decision problems (Churchman 1967). Instances of wicked decision problems occur naturally, for example, in engineering design (Marashi and Davis 2006) and e-democracy (Loukis, Xenakis, and Tseperli 2009; Gordon and Richter 2002). *IBIS* (Issue Based Information System) (Kunz and Rittel 1970) provides a powerful and widely adopted approach for knowledge representation especially suitable for wicked decision problems. While many tools for visualisation and collaborative development of IBIS graphs are available (Conklin et al. 2001; Bracewell et al. 2009; Aurisicchio and Bracewell 2013), automated decision support in this context is still underdeveloped, even though it would benefit several applications. *QuAD* (Quantitative Argumentation Debate) frameworks (Baroni et al. 2015) are a recently proposed IBIS-based formalism encompassing automated decision support by means of an algorithm for computing the *strength* of answers to decision questions, given an IBIS graph of a restricted kind (see (Baroni et al. 2015) for details). The calculation aggregates the strength of attacking and supporting arguments for the answers and for other opinions, recursively. The QuAD algorithm has been integrated within the *designVUE* tool[1] (Baroni et al. 2015) and the *Arg&Dec* system[2] (Aurisicchio et al. 2015) and has proven useful in several applications in engineering design.

Figure 1 shows an IBIS graph/QuAD framework as visualized in Arg&Dec. The graph is an abstraction of a real decision-making problem in design engineering, where the *Issue* node represents the question of how to control the ventilation in a room; the *Answer* nodes A1 and A2 are the available options, with A1="building management system control" and A2="user control"; the two *Pro Argument* nodes P1 and P2 support A1 and P3 supports A2, with P1="energy is saved", P2="elderly occupants require more simple settings" and P3="user satisfaction is increased"; the *Con Argument* nodes C2, C3 and C4 attack P2 and C1 attacks A2, with C1="user negligence can lead to losses", C2="user control systems are relatively simple", C3="elderly occupants who have difficulty will probably have carers" and C4="the building's target market is young professionals".

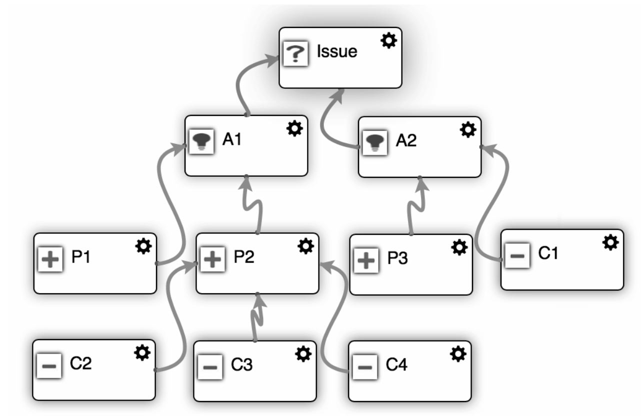

Figure 1: Example IBIS graph

QuAD frameworks admit Abstract Argumentation frameworks (Dung 1995) as an instance (Baroni et al. 2015), and the QuAD algorithm replaces standard semantic notions of acceptability, as in (Dung 1995), with a quantitative notion of strength, starting from a *base score* (or intrinsic strength) of answers and arguments. For example, assuming that each answer and argument in Figure 1 has a medium base score of 0.5, the QuAD algorithm determines, in particular, that A1 has strength 0.765625 and is thus stronger than A2, with strength 0.5. The higher strength of A1 reflects a higher level of support (albeit mitigated by the bottom layer of attacks).

As noted in (Baroni et al. 2015), the aggregation of opinions used in the QuAD algorithm causes a form of *discontinuity* of the notion of strength: for example, an opinion with very strong attackers and no supporter may have a strength of 0 (the lowest possible), but adding even a single very weak supporter for the opinion may increase its strength abruptly to a (comparatively) high value; dually, the strength of an opinion with very strong supporters and no attackers may jump from 1 (the highest possible value) to a (comparatively) low value. As discussed in (Baroni et al. 2015), this

[1] www3.imperial.ac.uk/designengineering/tools/designvue
[2] www.arganddec.com

behaviour may be suitable in some contexts but not in others.

In this paper we propose a novel, discontinuity-free algorithm, called *DF-QuAD*, for computing the strength of opinions in QuAD frameworks. We also prove several desirable properties of this algorithm, also exhibited by the original QuAD algorithm (Baroni et al. 2015), and, in addition, identify and prove a novel "discontinuity-freeness" property, not exhibited by the original QuAD algorithm. Furthermore, we identify special classes of QuAD frameworks for which the QuAD algorithm and the DF-QuAD algorithm coincide. We then compare the two algorithms in the context of two different application scenarios, engineering design and e-democracy, showing that both may be beneficial depending on the characteristics of the scenario. Finally, we show how the DF-QuAD algorithm may be used in a *reverse engineering* context, where recommendations are interactively given to users as to how to modify QuAD frameworks when there is a mismatch, due to incompleteness of information, between their intuition and the results of the DF-QuAD algorithm (e.g. the ranking of answers derived from it).

References

Aurisicchio, M., and Bracewell, R. 2013. Capturing an integrated design information space with a diagram-based approach. *Journal of Engineering Design* 24(6):397–428.

Aurisicchio, M.; Baroni, P.; Pellegrini, D.; and Toni, F. 2015. Comparing and integrating argumentation-based with matrix-based decision support in Arg&Dec. In *Proc. of the 3rd Int. Workshop on the Theory and Applications of Formal Argumentation, TAFA 2015*.

Baroni, P.; Romano, M.; Toni, F.; Aurisicchio, M.; and Bertanza, G. 2015. Automatic evaluation of design alternatives with quantitative argumentation. *Argument & Computation* 6(1):24–49.

Bracewell, R. H.; Wallace, K. M.; Moss, M.; and Knott, D. 2009. Capturing design rationale. *Computer-Aided Design* 41(3):173–186.

Churchman, C. 1967. *Wicked Problems*, volume 14. INFORMS.

Conklin, J.; Selvin, A. M.; Shum, S. B.; and Sierhuis, M. 2001. Facilitated hypertext for collective sensemaking: 15 years on from gIBIS. In *Proc. of the 12th ACM Conf. on Hypertext and Hypermedia*, 123–124.

Dung, P. M. 1995. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artif. Intell.* 77(2):321–358.

Gordon, T. F., and Richter, G. 2002. Discourse support systems for deliberative democracy. In *Proc. of the 1st Int. Conf. on Electronic Government, EGOV 2002*, 248–255.

Kunz, W., and Rittel, H. W. 1970. *Issues as elements of information systems*, volume 131. Institute of Urban and Regional Development, University of California Berkeley.

Loukis, E.; Xenakis, A.; and Tseperli, N. 2009. Using argument visualization to enhance e-participation in the legislation formation process. In *Proc. of the 1st Int. Conf. on Electronic Participation, ePart 2009*, 125–138.

Marashi, S. E., and Davis, J. P. 2006. An argumentation-based method for managing complex issues in design of infrastructural systems. *Rel. Eng. & Sys. Safety* 91(12):1535–1545.