The CREDO stack: from arguments and decisions to cognitive agents

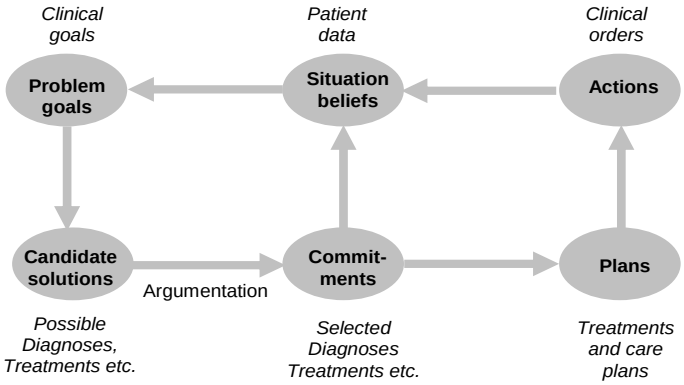
John Fox
Department of Engineering Science, Oxford University,
Department of Statistics, Warwick University

The CREDO stack is the result of a long-term research programme that was originally aimed at understanding human expertise, taking medical expertise as a model. The "stack" includes foundational theories about cognition and knowledge representation, and technologies for designing and delivering cognitive agents based on a set of general reasoning functions and their interactions.

Apart from its practical challenges medicine throws up many issues for theoreticians, such as how reasoning, problem-solving, decision-making and planning functions work together to achieve an agent's goals, and the nature of deliberative control and metacognition. Medicine is especially challenging because of the high levels of uncertainty that are endemic in everyday practice; the need to address multiple goals and constraints simultaneously; the constant changes in clinical situations that may require flexible responses, and the importance of learning from experience. A major feature of clinical practice and a challenge for AI generally is that any plan may prove to be mistaken so provision must be made for detecting when to revise earlier beliefs and decisions and update plans.

Key theoretical results from this research include a logical model for reasoning under uncertainty (evidential argumentation: 3, 5,10,11) an argumentation based theory of decision-making (1,4, 5,9), and a general architecture for autonomous cognitive agents (the domino architecture, 1, 6,7). The domino architecture illustrated below is an agent theory based on traditional cognitive modalities like beliefs, goals, commitments, plans in which each modality is a semantically distinct kind of data and the arrows represent logics that define the semantics of these modalities [1,4].

Argumentation is seen as pivotal to making commitments (deciding what to believe or what to do) though under certain definitions of argumentation every arrow represents a semantically distinct type of argumentation. In this model general knowledge is applied to specific situation data in order to construct arguments for and against alternative beliefs (e.g. diagnoses) or plans (e.g. treatments). This is summarized by the following signature where the



symbolic data above the line are the inputs to an argumentation logic and the arguments which are validly derivable under this logic are below the line.

$$\frac{\text{General knowledge} \cup \text{Situation data}}{\text{(Claim, Grounds, Qualifier)}}\ LA$$

In LA, a Logic of Argument (3,4) an argument is a triple consisting of a "Claim" (a tentative conclusion), "Grounds" (justification) and "Qualifier" (the confidence in the Claim warranted by the argument). A qualifier may indicate that an argument "supports" or "opposes" a claim, for example without requiring that the degree of support or doubt should be quantifiable. However quantitative schemes for expressing argument strength, such as Bayesian schemes can be viewed as a special form of argumentation within the theory.

An agent may be able to construct multiple lines of argument for and against competing diagnoses or treatments, each of which increases or decreases overall confidence. The more supporting (opposing) arguments there are for a claim the more (less) confidence we should have in it. We have called this form of argumentation the evidential mode in contrast to the dialectical mode that permits arguments to attack, rebut or undercut the arguments of other agents

(10). As in classical decision theory, but not classical logic, collections of arguments can be aggregated within the decision making framework to yield an overall measure of confidence in competing claims.

In his seminal The Uses of Argument the philosopher Stephen Toulmin has also pointed out that humans routinely use linguistic modalities such as "presumably…", "possibly…", "probably…" and their lexical and affixal negative forms; in the evidential framework linguistic modalities can be formalised as conditions for accepting claims based on collections of arguments (2).

The domino and supporting argumentation theory has proved to be a very successful foundation for developing practical technologies and applications in medical decision making and management of treatment. The PROforma language that is based on it (4, 6, 8) has been used in designing and deploying many operational applications in medicine (see also www.openclinical.net). Despite having its roots in the specific domain of medicine the domino architecture and CREDO software stack appear to be a promising basis for developing applications in other domains as well.

References

1. Das S, Fox J, Elsdon D, Hammond P "A flexible architecture for a general intelligent agent" Journal of Experimental and Theoretical Artificial Intelligence, 9, 407-440, 1997.
2. Elvang-Goransson M, Krause P J and Fox J "Acceptability of arguments as logical uncertainty" in M Clarke, R Kruse and S Moral (eds) Symbolic and Quantitative approaches to reasoning and uncertainty; Proc. European Conference ECSQUARU 93, Berlin: Springer Verlag, (1993) 79-84.
3. Fox J, Krause P J and Elvang-Goransson M "Argumentation as a general framework for uncertain reasoning", Proc. Int. Conf. On Uncertainty in Artificial Intelligence, Washington: Morgan Kaufman, 1993.
4. Fox J and Das S Safe and Sound: Artificial Intelligence in Hazardous Applications Cambridge MA: MIT Press (2000)
5. Fox J, "Probability, logic and the cognitive foundations of rational belief" J Applied Logic, 1, 3-4, 197-224, 2003.
6. Fox J, Beveridge M, Glasspool D "Understanding intelligent agents: analysis and synthesis" AI Communications (2003)
7. Fox J, Glasspool D, Modgil S A canonical agent model for healthcare applications, IEEE Intelligent systems, 2006.
8. Fox J, Cooper R, Glasspool D "A canonical theory of dynamic decision-making" Frontiers in cognitive science, 2012.
9. Fox J, Glasspool D, Grecu D, Modgil S, South M, Patkar V, "Argumentation-based Inference and Decision-Making – A Medical Perspective" IEEE intelligent systems, Nov/Dec, 2007, 34-41.
10. Fox J "Arguing about the evidence" in Philip Dawid, William Twining, Mimi Vasilaki (eds) Evidence, Inference and Enquiry London: The British Academy and Oxford University Press.
11. P Krause, S Ambler, M Elvang-Goransson, J Fox. "A Logic of Argumentation for Reasoning under Uncertainty" Computational Intelligence, 11, 113-131, 1995