Answer to Fangzhen Lin

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Thank you very much for the resumee you made from my article and for your very interesting questions. Here are my answers.

1. There are probably other properties. We can find some of them when we consider additional axioms for conditional logic such as Modus Ponens, Modularity, CV, ... The reason I did not discuss them all is that causality seems a very weak concept and should not have most of these properties. On the other hand, all existing approaches which are based in classical implication (such as Lins, Giordano et al. ...) have these properties. Other properties could concern imbricated causal operators. I did not find any action theory with a notion of causality allowing for nested causal operators.

   The property proposed by Fangzhen Lin

   'if p implies q, then p implies (q or r) for any r"

   is an instance of my property 8 (right weakening).

2. I am pretty sure that monotonicity of causal implication is a property which heavily restricts the range of its application even when causality is considered only in relation with action theories (which is the issue of my article). The causal theories which we consider are typically for issues of commonsense reasoning. Causal implication which is monotonic cannot cope with exceptions. It is then not possible to handle situations where an event or fact causes another event or fact, but does not cause it any more in the presence of other facts. As an example, consider Lin's suitcase example and add a new causal law expressing that the suitcase is not open whenever there is a leather belt around it keeping it closed. Let us denote the fact that there is a belt by the fluent l. Let us consider this example in Lin's theory:

   (1) $Caused(f, true, s) \to Holds(f, s)$
   (2) $Caused(f, false, s) \to \neg Holds(f, s)$
   (3) $Holds(up(1), s) \wedge Holds(up(2), s) \to Caused(open, true, s)$
   (4) $Holds(l, s) \to Caused(open, false, s)$
   (5) $Poss(flip(i), s) \to (\neg Holds(up(i), s) \to Caused(up(i), true, do(flip(i), s))) \quad i = 1, 2$
   (6) $Poss(flip(i), s) \to (Holds(up(i), s) \to Caused(up(i), false, do(flip(i), s))) \quad i = 1, 2$

   The frame law is

   $$(7) \quad \neg \exists v Caused(f, v, do(a, s)) \to (Holds(f, s) \leftrightarrow Holds(f, do(a, s)))$$

Let us denote by T_0 the conjunction of the laws (1) to (6). Then T_0 entails, by classical logic alone

$$\neg Holds(up(1), s) \vee \neg Holds(up(2), s) \vee \neg Holds(l, s) \text{ for any } s$$

This means that it is impossible to have both latches up and a leather belt fixed around the suitcase!

Let be $T_1 = T_0 \cup \{\neg Holds(up(1), s_0) \wedge Holds(up(2), s_0) \wedge Holds(l, s_0)$. We get then

$$\begin{array}{lcl} Circ(T_1; caused) & \vdash & \neg \exists v Caused(up(2), false, do(flip(1), s_0)) \\ Circ(T_1; caused) & \vdash & \neg \exists v Caused(l, false, do(flip(1), s_0)) \end{array}$$

Adding the frame law (7) to $Circ(T_1; caused)$ yields an inconsistent theory since we can deduce

$$Holds(up(1), do(flip(1), s_0)) \wedge Holds(up(2), do(flip(1), s_0)) \wedge Holds(l, do(flip(1), s_0))$$

Giordano et al. [2, 1] do not behave much better with this example. The theory

$$\begin{array}{lll} \Pi: & \Box(\neg up_1 \to [flip_1]up_1) & \Box(up_1 \to [flip_1]\neg up_1) \\ & \Box(\neg up_2 \to [flip_2]up_2) & \Box(up_2 \to [flip_2]\neg up_2) \\ & \Box(up_1 \wedge up_2 \to ©open) & \\ & \Box(l \to ©\neg open) & \\ \text{Obs:} & [\varepsilon](\neg up_1 \wedge up_2 \wedge l) & \\ \multicolumn{3}{l}{\text{Frame} = \{(l, a) : a \in \mathcal{A}, l \in \mathcal{F}\}.} \end{array}$$

has no extension!

I do not see how exceptions can be handled without considering non-monotonic inference.

3. The question of the representation language is very important. Given that we consider causality as a logical operator, should this operator be unary or binary? My intuition is that causality should be a binary relation. What does it mean to say that 'a is caused'? I think it means that there is something which caused (or causes) a, even if it is not precised what! I suppose one reason why in relation with action theories we can find essentially approaches where causality is a unary operator/predicate is that a unary modal operator seems technically easier to handle than a binary one. I do not agree however that the unary operator approaches are really sufficient for the representation of causality in action theories. The point is that with a unary operator, in most cases the causal implication will be represented by means of classical implication and this makes untreatable many problems which can occur in action theories.

References

[1] Laura Giordano, Alberto Martelli, and Camilla Schwind. Dealing with concurrent actions in modal action logic. In H. Prade, editor, *Proceedings of the 13th European Conference on Artificial Intelligence*, pages 537–541. John Wiley & Sons, Ltd, 1998.

[2] Laura Giordano, Alberto Martelli, and Camilla Schwind. Ramification and causality in a modal action logic. *Journal of Logic and Computation*, 1999. to appear.