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Japan Advanced Institute of Science and Technology

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法令文の中の不整合の検出

東条 敏

1. 否定(¬)の不整合 2. or(∨)の不整合 3. 含意(→)の不整合

Conceptual conflict

cf. Hagiwara (JURIX '06)

 $guilty \land \neg guilty \vdash \bot$ $guilty \land innocent \vdash \bot$ $possible \land impossible \vdash \bot$ $human \land car \vdash \bot$

Assumptive facts

$$P_1 \leftarrow Q_1, Q_2, Q_3. \
eg P_1 \leftarrow Q_2, Q_3, Q_4.$$

- $P_2 \leftarrow Q_1, Q_2, Q_3. \
 eg P_2 \leftarrow Q_1, Q_2.$
- $P_3 \leftarrow Q_1, Q_2, \neg Q_3.$ $\neg P_3 \leftarrow Q_1, Q_2, Q_3.$
- $orall x P_4 \leftarrow Q_1, Q_2, Q_3(x). \
 eg P_4 \leftarrow Q_1, Q_2, Q_3(a).$

Condito Sine Qua Non

"A caused B" if "if A had not happened, B would not have happened." (J. Glaser, 1858)

- 1. Lethal dose is 100mg.
- 2. A put 60mg.
- 3. *B* put 60mg.
- 4. If A had not put 60mg, C would not have died.
- 5. A is culpable for the death of C.

Condito Sine Qua Non – cont'd

- 1. Lethal dose is 100mg.
- 2. A put 120mg.
- 3. *B* put 120mg.
- 4. Even though A had not put 120mg, C would have died.
- 5. A is <u>not</u> culpable for the death of C??

Occam's razor

The more reasons are employed, the less plausible the result becomes.

 \downarrow

We need to find the minimal explanation. (Economy of reasoning)

Which is the minimal explation?

- $\bullet A_{120mg}$
- $\bullet B_{120mg}$
- $ullet A_{120mg} ee B_{120mg}$
- $ullet A_{120mg}$ or B_{120mg}

Minimal explanation

• A_{120mg} implies $A_{120mg} \lor B_{120mg}$.

Minimal explanation

- A_{120mg} implies $A_{120mg} \lor B_{120mg}$.
- \bullet If A_{120mg} caused C_{died} , then $A_{120mg} \lor B_{120mg}$ caused C_{died} ?

Minimal explanation

- A_{120mg} implies $A_{120mg} \lor B_{120mg}$.
- \bullet If A_{120mg} caused C_{died} , then $A_{120mg} \lor B_{120mg}$ caused C_{died} ?
- If yes, then $A_{120mg} \vee B_{120mg} \vee D_{120mg} \vee E_{120mg}$ caused C_{died} . The cause is obviously too weakened.

Formalization in Abduction

- **B** Background theory
- C Set of facts
- **O** Observation

 $B\cup C\models O$

In our case,

- B Known rules
- C Possible causes
- **O** Result

 $\{A_{120mg} \supset C_{died}\} \cup \{A_{120mg}\} \models \{C_{died}\}$

(i) C.S.Q.N. by Belief Revision

T * P: revision of T by P, is the set of maximal consistent subsets of $T \cup P$ including P.

Ex.

$$\{\alpha \supset \beta, \alpha\} * \{\neg \beta\}$$
 is either $\{\alpha \supset \beta, \neg \beta\}$ or $\{\alpha, \neg \beta\}$

First approximation: for any S in $B \cup \{C * \{\neg A\}\}$, $S \not\models O$ (unless A, not O), then A is a cause of O.

 \downarrow

In order to entrench B, we revise the above as: for any S in $C * \{B \cup \{\neg A\}\}$, $S \not\models O$, then A is a <u>cause</u> of O. A is a <u>critical cause</u> if there is no A' such that $A' \models A$. 13

$$\begin{cases} B = \{A_{120} \supset C_{died}, \ B_{120} \supset C_{died} \}\\ C_1 = \{A_{120}, \ B_{120} \}\\ O = C_{died} \end{cases}$$

$$A_{120} \text{ is } \underline{\text{not}} \text{ a cause.} \\\begin{cases} B \cup C_1 \models C_{died} \text{ and} \\C_1 * (B \cup \{\neg A_{120}\}) \ni B \cup \{\neg A_{120}, \ B_{120} \}\\ \text{entails } C_{died} \end{cases}$$

$$A_{120} \lor B_{120} \text{ is a } \underline{\text{cause.}} \\\begin{cases} B \cup C_1 \models C_{died} \text{ and} \\C_1 * (B \cup \{\neg (A_{120} \lor B_{120})\}) \ni B \cup \{\neg A_{120}, \ B_{120} \}\\B \cup \{\neg A_{120} \land \neg B_{120} \}\\B \cup \{\neg A_{120} \land \neg B_{120} \}\\ \text{does } \underline{\text{not}} \text{ entail } C_{died} \end{cases}$$
Furthermore, $A_{120} \lor B_{120}$ is a $\underline{\text{critical cause.}}$

-

Example 2

$$\begin{cases} B = \{A_{120} \supset C_{died}, \ B_{120} \supset C_{died}\} \\ C_2 = \{A_{120} \lor B_{120}\} \\ O = C_{died} \end{cases}$$

$$A_{120} \text{ is } \underline{\text{not}} \text{ a cause.} \\ \begin{cases} B \cup C_2 \models C_{died} \text{ and} \\ C_2 * (B \cup \{\neg A_{120}\}) \ni B \cup \{\neg A_{120}, A_{120} \lor B_{120}\} \\ \text{entails } C_{died}. \end{cases}$$

$$A_{120} \lor B_{120} \text{ is a } \underline{\text{cause.}} \\ \begin{cases} B \cup C_2 \models C_{died} \text{ and} \\ C_2 * (B \cup \{\neg (A_{120} \lor B_{120})\}) \ni B \cup \{\neg A_{120} \lor B_{120}\} \\ B \cup \{\neg A_{120} \land \neg B_{120}\} \} \end{cases}$$

$$B \cup \{ \neg A_{120} \land \neg B_{120} \}$$

$$B \cup \{ \neg A_{120} \land \neg B_{120} \}$$

$$B \cup \{ \neg A_{120} \land \neg B_{120} \}$$

$$B \cup \{ \neg A_{120} \lor B_{120} \}$$
Furthermore, $A_{120} \lor B_{120}$ is a critical cause.

Problems of C.S.Q.N.

Example 1 shows:

- A_{120} is not a cause though A should be blamed.
- $A_{120} \lor B_{120}$ is a cause.
- $A_{120} \lor B_{120}$ is a critical cause.

Exmaple 2 shows:

- A_{120} is not a cause.
- $A_{120} \lor B_{120}$ is a cause.
- $A_{120} \lor B_{120}$ is a critical cause.
- But if A_{120} is a cause, $A_{120} \lor B_{120}$ is also a cause.

C.S.Q.N. does not satisfy Occam's razor.

(ii) Solution by Minimal Abduction

- **B** Background theory
- H Abducibles (a set of propositional formulae)O A propositional formula
- $E \ (\subseteq H)$ is an explanation iff
 - $B \cup E \models O$ and $B \cup E \not\models \bot$.
 - E is minimal if for any $E' \subset E$, $B \cup E' \not\models O$.

Example 1 – revisited –

When $H = \{A_{120}, B_{120}\}$, the minimal explanations of *O* becomes $\{\{A_{120}\}, \{B_{120}\}\}$. That is,

either A_{120} or B_{120} is the minimal cause.

In other words, there are two minimal explanations.

Example 2 – revisited –

When $H = \{A_{120} \lor B_{120}\}$, the minimal explanations of O becomes $\{\{A_{120} \lor B_{120}\}\}$. That is,

 $A_{120} \lor B_{120}$ is the minimal cause.

Issue 1: Logical Implication and Causation



In our case,

$$A_{120} \supset_{implies} (A_{120} \lor B_{120}) \supset_{causes} C_{died},$$

But

 $A_{120}
ot \supset C_{died}.$

cf. Deduction theorem: $\alpha \vdash \beta \iff \vdash (\alpha \supset \beta)$.

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Issue 2: Scope of a predicate

(A or B) put 120mg vs. (A put 120mg) or (B put 120mg)

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(A or B) put 120mg vs. (A put 120mg) or (B put 120mg)

$K_A(lpha ee eta) eq K_A lpha ee K_B eta$

Issue 2: Scope of a predicate

(A or B) put 120mg vs. (A put 120mg) or (B put 120mg)

$A \not\supset A \lor B$ (substructural logic)

Summary

- Formalization of C.S.Q.N. to clarify its paradox.
- Minimal explanation, to distinguish between disjunction of causes and a disjunctive cause.

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